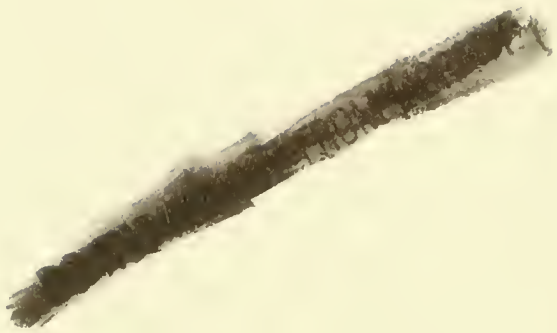

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CLXXV.

(Vol. VIII.—January, 1879.)

THE FLOW OF WATER IN SMALL CHANNELS,

AFTER GANGUILLET AND KUTTER, WITH KUTTER'S DIAGRAM MODIFIED, AND GRAPHICAL TABLES WITH SPECIAL REFERENCE TO SEWER CALCULATIONS.

By R. HERING, C. E., Member of the Society.

READ OCTOBER 16TH, 1878.

One of the most interesting problems in the science of hydraulics has always been that of obtaining a correct mathematical expression for the value of the mean velocity in a stream of water. Much thought, labor and money have been expended in the search for a general formula which should give reliable results. Until recently all efforts had failed

to provide any that could be depended upon, beyond the conditions under which the observations for its deduction were made. One would be accurate only for pipes, and another only for canals in earth, still another only for large rivers with very light gradients, and so on. In the year 1869, Ganguillet and Kutter succeded, by an ingenious synthesis, in developing a new formula from the many existing reliable measurements, which is applicable under all conditions, while being at least as correct as any of the preceding ones in the cases to which they are limited.

The great importance of the degree of roughness of the wetted perimeter had been entirely overlooked until the experiments of D'Arcy and Bazin brought it into notice in 1865. In fact, Dubuat had stated that the velocity was *independent* of the material forming the perimeter. This indispensable element they now, for the first time, introduced in its full bearing into a general formula, whereby the problem of finding the mean velocity without actual experiment seems at last to have reached a somewhat satisfactory solution.

The results of these investigations were first brought to the notice of American engineers by Mr. Jackson's translation of some of Kutter's writings,* and also by a complete exhibit of his works on the subject in the Swiss Department of the Centennial Exhibition at Philadelphia in 1876.†

The formula of Ganguillet and Kutter reads as follows: §

$$v = c\sqrt{Rs} \qquad 1.$$

in which the co-efficient c is variable and determined by the equation,

$$c = \frac{y}{1 + \frac{x}{\sqrt{R}}} \qquad 2.$$

---

* 1. Hydraulic Manual, by L. D'A. Jackson, London, 1875.

2. The new Formula for the mean velocity of discharge of rivers and canals, by W. R. Kutter, transl. by L. D'A. Jackson, London, 1876.

† I. Versuch für die Aufstellung einer neuen Formel für die Bewegung des Wassers in Canälen und regelmässigen Flussstrecken. Von Ganguillet und Kutter. Aus der Zeitschrift des Oestreichischen Ingenieur und Architecten Vereins. Wien, 1869.

2. Die neuen Formeln für die Bewegung des Wassers in Canälen und regelmässigen Flussstrecken. Von W. R. Kutter. Aus der Allgemeinen Bauzeitung. Wien, 1870. Und aus dem Cultur Ingenieur. Wien, 1869 und 1870.

3. Diagram of the formula of Ganguillet and Kutter, mounted for practical use.

§ v = mean velocity.

R = mean hydraulic radius.

s = slope or tangent of inclination of the water surface.

n = co-efficient indicating the degree of roughness of the wetted perimeter.

In metric measure the two variables are,

$$y = 23 + \frac{0.00155}{s} + \frac{1}{n} \qquad 3.$$

$$x = \left(23 + \frac{0.00155}{s}\right) n$$

In English measure they are

$$y = 41.659 + \frac{0.0028075}{s} + \frac{1.8113}{n} \qquad 4.$$

$$x = \left(41.659 + \frac{0.0028075}{s}\right) n$$

As this formula is too complicated for practical use, Kutter supplemented it by a diagram which makes the solution extremely easy, as the values sought for may be read from the figure without any calculation.

The diagram at the Exhibition and also the one contained in Jackson's translation are intended to show the general application of the formula to large rivers as well as to small channels. In using it for the latter alone it is found to be rather too small for the required accuracy. Desirous of making the best use of this convenient graphical representation for obtaining the proper sizes of sewers, the writer plotted it to a large scale and confined it to grades between ∞ (vertical) and 1:2500, and to channels with a mean hydraulic radius of less than 9 feet. In this form it served the purpose much better. One inconvenience, however, was still felt when frequently used.

Kutter's diagram merely gives the values of the co-efficient c in the formula 1., but still leaves two multiplications and one extraction of a root to be made in order to find the velocity. By a simple device, this small deficiency was then supplied, allowing the mean velocity to be read off at once, with at least the same degree of accuracy as the data will warrant; namely, by considering that equation 1., may be written,

$$\frac{v}{\sqrt{R}} = \frac{c}{\sqrt{\frac{1}{s}}} \qquad 5.$$

a clue is given for the graphical construction of v. By plotting the values of c and $\sqrt{\frac{1}{s}}$ on one side and those of v and $\sqrt{R}$ on the other side of an angle, the corresponding relations will be represented by similar triangles.

In Kutter's diagram the co-efficients, c, are plotted on the vertical, the values for $\sqrt{R}$ on the horizontal axis; therefore, by graduating an additional scale of grades $\left(\sqrt{\frac{1}{s}}\right)$ on the former, and of velocities on the latter axis, the graphical solution is complete. The mean velocity of water flowing in any small channel, for any degree of roughness of perimeter and for a grade steeper than 1:2500, may be obtained in a few seconds, with a sufficient degree of accuracy and without any calculation.

This diagram, as thus completed, is herewith presented (see Plate I.), partly, because the only one generally accessible to English engineers (contained in Jackson's translation) is on a small scale, and, unfortunately, distorted so as to give values of c for smooth perimeters as much as 5 per cent. too low; partly, because the only published tables of Kutter's co-efficients, c, for English measure (contained in Jackson's Manual), which were, probably, taken from this diagram, contain the same error; and, partly, because I believe that in its modified form it may be useful to some of the members in the proportioning of small channels, sewers or pipes, and in ascertaining their true capacity when in various stages of dilapidation, and when built regardless of the value of smoothness—questions which often arise.

It is briefly described as follows: The vertical axis in the centre has the co-efficients, c, graduated on the left and the grades on the right hand side; the horizontal axis has the mean radius marked above and the mean velocity below it. To the left are four hyperbolic curves, indicating grades from ∞ to 0.04 feet per hundred, which is the limit of the diagram. They are intersected by lines radiating from a certain point, obtained by experience, equivalent to R=3.28 feet, or, by chance, one metre. These lines represent various degrees of roughness of the wetted perimeter, as noted. Commencing at the top with the smoothest surface experimented upon, being well-planed timber, they descend through gradually increasing degrees of roughness to the most irregular channels, greatly impeded by vegetation and detritus.

The construction of the diagram is, therefore, very simple. The proof of its being a correct representation of the values for Kutter's co-efficients would lead too far,* and it is merely our purpose to add the principles

* See Kutter's article in the "Zeitschrift des Oestreichischen Ingenieur und Architecten Vereins," mentioned above.

and necessary figures, by the aid of which it can be re-plotted, if required, to any scale.

Location of the points of intersection of the hyperbolas with the radial lines.—The values of y and x in Equation 2, are the co-ordinates for the hyperbolas. By substituting their values for English measure (see Eq. 4), also the grade to be indicated by the desired curve, and the value for the degree of roughness ranging from .009 to .040, as shown on the diagram, we obtain the co-ordinates of the respective points of intersection with reference to the two axes. To facilitate a plotting to any scale, or a direct calculation of the co-efficient, c, from the formula 2, the numerical values of y and x are given in Table I for four values of s, or the four hyperbolas marked "Grade Curves" on the diagram, and covering a range of grades from the vertical down to 1:2500. For convenience in using the diagram, these curves have been designated as a grade per hundred (g), instead of as the tangent of slope (s).

Co-efficients (c.)—The graduation for the co-efficients, c, is the same scale as that of the ordinates of the curves.

Grades (g).—To make the drawing as practical as possible, a value like $\sqrt{\frac{1}{s}}$ in Eq. 5, must be avoided, even at the expense of not having a regular scale, as it entails calculation. Grades are most conveniently given in feet per hundred, and they should be so plotted. If g is the grade per hundred and s the tangent of slope, then, instead of $\sqrt{\frac{1}{s}}$ we get $10\sqrt{\frac{1}{g}}$. This expression will give a quadratic scale of the reciprocals of the grade. It is now assumed that the lightest grade (g=0.04) shall coincide with the co-efficient, c=250; then, in order to locate all the grades in the scale of the co-efficients (*i. e.*, the ordinates of the hyperbolas), 250 would have to be equal to $10\sqrt{\frac{1}{0.04}}\times$ a constant, which is, therefore, 5. If we multiply all the values of $10\sqrt{\frac{1}{g}}$ by 5, we have the desired locations. Table II. contains the numerical values under the above assumption.

Mean Radii (R).—The scale by which the abscissas of the hyperbolas are plotted must be the same as the one for the values of $\sqrt{R}$. Instead of maintaining the linear scale, as Kutter has done on his diagram, sent

to the Exhibition, it was preferred to plot the values of R, giving a quadratic scale, in order to avoid the necessity of extracting a root. The location of the points, then, can be taken immediately from a table of square roots. For instance, the value $R=2$ would be plotted at a point measuring $\sqrt{2}=1.414$ from the origin in the scale of the abscissas for the hyperbolas.

Velocities (v).—In eq. 5, v is a quantity of the first degree, and its scale will, therefore, be a linear one. By substituting the values of $c=250$ and $s=0.0004$, which are located by the same point, and by selecting $R=9$, we determine the corresponding velocity as being $v=15$ feet. Then, at the point indicated by $R=9$ on the quadratic scale, or by $\sqrt{R}=3$ on the linear scale of the abscissas, we would have to mark a velocity=15 feet, *i. e.*, 5 times the value of $\sqrt{R}$; or, in other words, the same constant used in reducing the scale of grades to that of the ordinates, is likewise used for plotting the velocities in the scale of the abscissas of the curves.

For our own use we have marked off the values of R for circular sewers from 1 foot to 20 feet in diameter when running full or half full; they may serve here as an illustration. It must be remembered, as the original experiments were all made in open channels, that the formula is strictly not applicable to sewers running *full*. But, in want of further experiments, we are obliged to apply it also under this condition, and, as the results will be nearly if not exactly the same, it is safe enough to do so.

The diagram, as thus completed, contains the relation of the following 5 quantities in a practical form:

Mean velocity in feet per second.....	(v)
Kutter's co-efficient for English feet.....	(c)
Mean hydraulic radius in feet.....	(R)
Grade of water surface in feet per hundred...	(g)
Degree of roughness of wetted perimeter....	(n)

Their separate values are obtained by two operations, one giving the relation of the first four, the other that of the last four quantities.

The latter are all found on a straight line in such a manner that any three being given the fourth can be found as follows:

Given: R, g, n; Sought: c.—Join the point R on the axis of abscissas and the intersection of the line n with the curve g by a straight line.

Where it cuts the axis of ordinates will be found the proper value for c.

Given: R, c, g; *Sought:* n.—Join the point R, on the axis of abscissas, with the point c, on the axis of ordinates, by a straight line; prolong it until it intersects the grade curve representing g; at this point read off the value for n.

Given: c,g,n,; *Sought:* R.—Join the point where the radial line n intersects the curve g with the point c, on the axis of ordinates, by a straight line; prolong it down to the axis of abscissas, where it will indicate the value of R.

Given: R, c, n; *Sought:* g.—Join the point R, on the axis of abscissas, with the point c, on the axis of ordinates, by a straight line; prolong it until it intersects the given radial line n; here will be found the value of g, as represented by the "grade curves."

The other relation represented on the diagram is between the values for v, c, R and g, which form the terms of a proportion, and are, consequently, situated on two parallel lines in such a manner that a line joining the points indicating R and g will always be parallel to a line joining the corresponding values of v and c. Therefore, any three points being given the fourth can be readily found and the desired quantity at once read off.

The combined operation will now be as follows: Among the ten possible cases, if any three of the quantities are given, with the single exception of R, c and n (which allows g to vary as the square of v), the other two can be found on the diagram as described.

Case 1.—*Given:* n=0.017, *representing a channel built of good rubble masonry,* g=0.06 *feet per hundred,* R=1.25 *feet being the value for a semi-circular channel* 5 *feet in diameter. Sought: the mean velocity,* v.—Join the intersection of the line indicating n=0.017 with the curve corresponding to a grade g=0.06 and the point R=1.25 by a straight line (see the dotted lines on the diagram showing this example). This line intersects the axis of ordinates at a point giving a value for c of 89.6. Then place a ruler to join the point R=1.25 and the point on the axis of ordinates indicating the grade g=0.06, move it down parallelly until it intersects the value for c=89.6 as just found, and mark the intersection with the horizontal axis, where the desired mean velocity, v=2.45, is at once read off.

CASE 2.—*Given:* $g=0.06$, $R=1.25$, $v=2.45$. *Sought: the corresponding degree of roughness, n, indicating how smooth the perimeter must be constructed to maintain the above velocity**

The operation in this case will be reversed. Join the points marking $R=1.25$ and $g=0.06$ on the two axes, draw a line parallel to this through the given point $v=2.45$, and where it intersects the vertical axis c will be found to be $=89.6$. Then join this point c with $R=1.25$ by a straight line, prolong it until it intersects the grade curve corresponding to $g=0.06$, and at that point will be found the value for n (0.017), giving the greatest degree of roughness allowable to maintain the required velocity.

CASE 3.—*Given :* $R=2.5$, $n=0.011$ *and* $v=5.5$. *Sought : The grade g to produce this velocity.*

Unite the points indicating $R=2.5$ and the intersection of the line $n=0.011$ with the grade curve, for which an approximate value must be estimated, by a straight line, and find the value of c on the axis of ordinates to be 159.5. Join this point with $v=5.5$, and move the ruler parallelly until it intersects the horizontal axis at the value of $R=2.5$. The desired grade can then be read off on the vertical axis, and is found to be $g=0.0475$. Should this result deviate greatly from the value approximated for the grade curve, one repetition of the operation will always rectify it.

CASE 4.—*Given : n, g and v. Sought : R.*

Here it becomes necessary, first to approximate a value for R, in order to find one for c in the manner described before, and then, by joining c with v and drawing a parallel line through g, we intersect a truer value for R. Several repetitions will have to be made in order to get a correct result.

The other cases, which rarely occur, can be solved in a similar manner.

As to the accuracy of this graphical proceeding, we will find it to be not less than that of the data which are at our disposal. The values for R and g can of course be obtained very exactly in practice, but not those of v and n without a series of experiments. Supposing that we cannot be sure whether the roughness of the wetted perimeter in a

* To avoid confusion on the diagram in illustrating this example, the same points have been selected as in Case 1.

certain case is represented by $n = 0.010$ or $= 0.011$, which means a smoothness equivalent to plaster in pure cement or cement with one-third sand, which, with a little carelessness of workmanship in finishing, would be quite probable; or, that we cannot decide as to the amount of stones and weeds in a channel, *i. e.*, between $n = 0.028$ and $n = 0.032$, which would also be quite probable; then we can see from the diagram that the co-efficient c cannot be determined within about ten per cent. of its true value without a series of experiments. But, granting a possible error of only five per cent. on the scale of the co-efficients, we get a corresponding uncertainty of five per cent. for the velocities, resulting merely from the inability to judge of the exact value of n. The question then is: can the velocities be obtained on a chart of the scale of Plate 1 within a distance corresponding to five per cent. of their values?

The sources of error, if leaving out the inaccuracies in plotting the diagram and the unequal shrinkage of the paper, which latter may be avoided by mounting, will be: the estimating or reading of points on the scales, the uncertainty of intersections when acute, and the difficulty of ruling a long line parallel to a short one. Points on a scale may be conveniently read inside of $\frac{1}{50}''$, and for all practical cases the most acute intersections would be about 15°, making a possible error in reading from these two causes of less than $\frac{4}{50}''$, corresponding to 0.6 per cent. at the greatest velocity and to 2 per cent. at a velocity of 1 foot. The error resulting from drawing a long line parallel to a short one is greatest at 20 feet velocity. If we take an extreme case, in considering the line eight times longer, and start with an assumed maximum error of $\frac{4}{50}''$ in the short one, we get $\frac{32}{50}''$ as a possible inaccuracy in the reading of the velocity, which is still less than five per cent. With a little care, however, the ordinary values can be obtained from the diagram in its present scale within one per cent, whereas the calculated values cannot be depended upon within five per cent., except when based upon experiments for the special case in question.

In the foregoing we have a simple and reliable method for solving the general problem of the flow of water in small channels. In practice, however, two of the quantities, namely, the co-efficient c and the mean radius are not often directly considered; and we have instead usually to deal with two others, the size and discharge. Therefore, to complete the problem, we must finally get the relation of size, discharge, grade, velocity, and roughness into a practical and convenient form.

In substituting a relation for the size in place of the mean radius, we meet this difficulty; although the former defines the latter, the mean radius, conversely, will not determine the size, unless the shape of the section is also given. A general solution is therefore impossible, and it is limited at the outset by the condition that the channel in question must have a known shape, *i. e.*, either a circular, egg-shaped, rectangular, or other section. Then we may obtain its size and discharge by calculation after finding the value of the mean radius, as indicated in Case 4.

But for frequent use a far more convenient mode of obtaining the desired quantities is by means of numerical or graphical tables prepared for the required shape. A set of *numerical* tables is contained in Jackson's translation of one of Kutter's articles, already referred to. They are in metric measure for channels with straight bottoms and side slopes, and for the co-efficients $n = 0.025$, 0.030, 0.035, which are therefore only applicable to canals in earth and rivers. To prepare others for English measure for different values of n and for different shapes would entail a great amount of calculation, but it may be much reduced by applying the graphical method in such a scale as the degree of accuracy to be attained necessitates.

For almost all the ordinary cases in practice, however, *graphical* tables will be more convenient and sufficiently accurate, and it remains to be shown how they can be constructed and used.

As the above mentioned five quantities stand in a definite relation, four are variable, while the fifth remains a constant for the whole. There being fewer values for n than for any other quantity, it will be most expedient to make a table for each one of them. The discharges and grades requiring the greatest number of values to be represented ought to be graduated on the co-ordinate axes, causing the sizes and velocities to appear as curves. The size curves will all pass through the origin or zero point, as they must give a discharge $= 0$ at a grade $= 0$. The velocity curves will therefore cross them, and the co-ordinates of the points of their intersection can be determined by the following equations, if d denotes the discharge in cubic feet per second and a the area of water section:

$$d = v \times a \qquad 6.$$

$$s = \frac{v^2}{c^2 R} \qquad 7.$$

Substituting the values for the velocity and the size, we find that, in Equation 6, d will give the *ordinate* measured on the axis where the discharges are graduated, and, by Equation 7 which is another form of Equation 1, that we can obtain the value of s on the diagram, as shown above in Case 3. Remembering that the scale is marked in terms of g instead of s, we obtain at once the value needed for plotting. This value of g will be the *abscissa* of the point of intersection measured on the axis where the grades are marked. By using cross section paper, and noting the grades along the top and the discharges at the side, the two classes of curves may be readily plotted by means of these two equations.

A set of Graphical Tables, as thus developed in general, is annexed. Being intended for the ordinary requirements of sewer construction, they are confined to circular and to one form of egg-shaped sections, and are calculated for three values of n, namely, 0.011, 0.013 and 0.015, indicating the general range for good work. In Table III. are given various values of n, with reference to sewer construction, deduced from actual experiments, and also a suggestion of the degrees of roughness corresponding to the above three selected values.

Plate II. represents the relations for pipe sewers from 6″ to 36″ in diameter, Plate III. those for egg-shaped sections from 1′ 6″ × 2′ 3″ to 6′ × 9′ section, and Plate IV. those for circular sewers from 3′ to 16′ in diameter, covering the usual range of each kind. The limits of grade and discharge were regulated by the velocity which was assumed as having a practical maximum in pipes of 12′ per second, in the egg-shaped sewers of 14′ and in large circular sewers of 16′ per second.*

The plotting of these tables has been greatly facilitated, without effecting the accuracy to any practical extent, by the following considerations: In equation 4, the quotient, $\frac{.00281}{s}$, which varies with the grade, can be considered as a constant factor without making a serious

* It appears probable that the co-efficient of roughness is practically greater when the velocity is very high than when it has ordinary values. For, slight undulations in the surface, owing to imperfect construction, seem to act as additional resisting projections when passed at a high rate of speed, and thereby increase the co-efficient of roughness for the whole surface, which in turn again lowers the velocity. If we should find a theoretical velocity of twenty feet for a channel whose roughness is equal to 0.013 with ordinary velocities, it would be likely that this high velocity is not attained, but only one which would correspond to an increased roughness, perhaps to 0.015 or 0.017, according to the amount of general undulations in the surface of the work. For this reason, and because the writer has not found many reliable measurements of higher velocities, the tables were confined to the above limits.

error for the present application, and its value, which is very small for grades steeper than 1:2 500, can always be selected so that the error will be on the safe side.* Equations 4, 2 and 1 combined will then be reduced to

$$v = \text{constant} \times \sqrt{s}$$

$$\text{then also } d = \text{constant} \times \sqrt{s}$$

which indicates that the curve representing a sewer of a certain size is a *parabola*, the discharges d being the ordinates and the slopes s the abscissas. Instead of drawing a parabola for each size, we can further simplify the plotting by considering that if the abscissas are graduated in a scale of square roots, the parabola itself becomes a straight line. Then, by marking the grade, see the top of each table, so that they increase as the square roots of their values, the parabolas representing the sizes will be straight lines, as shown. A concomitant advantage is secured hereby for marking off the intersections with the velocity curves. Namely, for a constant size, $d = \text{constant} \times v$, where v varies directly as the discharge and can be graduated in a regular scale. Then we have only to calculate *one* intersection in terms of discharge and grade by means of equations 6 and 7, and then simply to proportion the others. For instance, by substituting a velocity of 16 feet and a size of 6 feet diameter, and $n = 0.011$, we find

$$d = 452 \text{ cubic feet per second,}$$

$$\text{and } g = 0.77 \text{ feet per hundred.}$$

Then, plotting this point of intersection, we draw a straight line from it to the zero point. If we desire to have a curve for every two feet of velocity, as in our tables, this line, which now represents the relations for a circular channel six feet diameter, is divided into eight equal parts, each determining respectively the intersections of the curves 2, 4, 6, etc., to 16 feet per second.

The simplicity of thus plotting these tables is apparent. They can be rapidly made on cross-section paper, in the manner designated, if desired, to suit particular circumstances, viz., to a larger scale, for other sizes, other shapes or co-efficients of roughness, for greater discharges, and when the sewer is running but partially filled.

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* The effect of this quotient is represented on Kutter's Diagram by the "Grade curves." For a channel about 13 feet in diameter, the effect of varying them for the same degree of roughness is not at all perceptible, but the smaller the diameter the greater is their influence. Then it will be safe to assume, as a constant for each size, the curve representing the *lightest* grade to which it is desired to build it.

It may be worth while to mention that in using the tables for sewers intended to carry off an amount of water equivalent to a rainfall of one inch per hour, the scale to the left indicating the discharges in cubic feet per second may also be considered as the scale of acres drained. One acre, or 43 560 square feet, would discharge $\frac{43560}{12}$ cubic feet of rain water per hour, or $\frac{43560}{12 \times 60 \times 60} = 1.0083$ cubic feet per second, therefore the scales are very nearly identical.

The use of the tables is illustrated as follows : Being on a small scale, the values obtained are not more than a close approximation, which is sufficient, nevertheless, for nearly all requirements.

1. Given : 500 acres to be drained of a one-inch rainfall, the available grade g being 0.3 per 100. Sought : the diameter of a circular sewer, built of good brickwork ($n = .013$).

On Plate IV., for $n = .013$, we find the horizontal line indicating a discharge of 500 cubic feet per second being equivalent to the drainage of 500 acres under the above assumption. Where this intersects the vertical line indicating the grade 0.3, we at once read off the requisite diameter of eight-feet and a velocity of ten feet per second.

2. Given: an egg-shaped sewer 4′x 6′ section, smoothly plastered with cement mortar ($n = .011$), with a grade of .065 feet per 100, Sought : the discharge when running $\frac{2}{3}$ full.

On Plate III, for $n = 0.011$, we find that the ray indicating the size 4′x 6′ intersects the vertical line for the grade =.065 at a point showing the corresponding discharge to be 48 cubic feet, and the velocity 4 feet per second.

The tables will also give the grade and velocity by inspection, in the same manner, if the other quantities are known ; but for these other cases, it will be better to obtain the unknown quantities directly from the diagram, as shown above in Cases 1, 2 and 3.

All the known elements occurring in the problem of the flow of water in small channels, giving the results in conformity with the formula of Ganguillet and Kutter, can, therefore, be arranged in a convenient and practical form. The diagram will give the values of v, n, c and g in a few moments, and the tables, prepared for special shapes of water section will give the size and discharge at a glance, and by examining the effects of slight variations of size or grade, will enable the engineer easily to determine the most economical design.

In order to present more clearly to the eye the great importance of the degree of roughness, from an economical point of view, three sketches are added on Plate V, showing the conditions of three circular sewers of 1, 5 and 10 feet diameters running full. The ordinates denote the discharges and velocities; the abscissas, for simplicity plotted in a quadratic scale like the previous tables, indicate the grades. The pencil of rays represents various degrees of roughness from $n = .010$ to .030, *i. e.*, from a plaster of pure cement to a stony soil with a few plants. A glance at these sketches will at once show the great influence of the roughness on the discharge. A closer examination will prove that the effect increases with the smoothness of the wetted perimeter, and inversely as the size.

Therefore, the smaller the channel the better it will pay to increase the degree of smoothness to its highest practical limit. For instance, considering an open semi-circular channel 3 feet in diameter, at a grade of one foot per hundred; when built of rough rubble masonry, slightly damaged ($n = .019$), the mean velocity will be 6.2 feet per second. But when the same channel is carefully plastered with pure cement, or painted with a thick coat of natural asphalt ($n = .010$), it will give for the same grade a velocity of 13.00 feet per second, or more than *double* the discharge of the other.

The great gain in the carrying capacity of small sewers by using well laid glazed terra cotta pipes is, therefore, fully confirmed by the general formula of Ganguillet & Kutter.

Table I.

Location of Grade Curves

Or the values in English measure of x and y in the Equation $c = \dfrac{y}{1 + \sqrt{\dfrac{x}{R}}}$

	$g = \infty$, $s = \infty$		$g = 1.0$, $s = 0.01$		$g = 0.1$, $s = 0.001$		$g = 0.04$, $s = 0.0004$	
n	x	y	x	y	x	y	x	y
.008	.3333	268 068	.3355	268.349	.3558	270.875	.3894	275.087
009	.3749	242.911	.3775	243.192	.4002	245.718	.4381	249.930
.010	.4166	222.772	.4194	223.053	.4447	225.579	.4868	229.791
.011	.4583	206.320	.4613	206.601	.4892	209.127	.5355	213.339
.012	.4999	192.599	.5033	192.880	.5336	195.406	.5842	199 618
.013	.5416	180.987	.5452	181 268	.5781	183.794	.6328	188.006
.014	.5832	171.035	.5872	171.316	.6225	173.842	.6815	178.054
.015	.6249	162.410	.6291	162.691	6670	165.217	.7302	169.429
.016	.6666	154 863	.6710	155.144	.7115	157.670	.7789	161.882
.017	.7082	148.204	.7130	148.485	.7559	151 011	.8276	155.223
.018	.7499	142.285	.7549	142.566	.8004	145.092	.8762	149.304
.019	.7915	136.989	.7969	137.270	.8449	139 796	.9249	144.008
.020	.8332	132.222	.8388	132.503	.8893	135.029	.9736	139.241
.021	.8749	127.910	8807	128.191	.9338	130.717	1.0222	134.929
.022	.9165	123 982	.9227	124.270	.9783	126.796	1.0709	131.008
.023	.9582	120.410	.9646	120.691	1.0227	123.217	1.1196	127 429
.024	.9998	117.129	1.0066	117 410	1.0672	119 936	1.1683	124.148
025	1.0415	114.110	1.0485	114.391	1.1117	116.917	1.2170	121 129
.026	1.0832	111.323	1.0904	111 604	1.1561	114.130	1.2656	118.342
.027	1.1248	108.743	1.1324	109.024	1.2006	111.550	1.3143	115 762
.028	1.1665	106.347	1.1743	106.628	1.2450	109 154	1.3630	113 366
.029	1.2081	104.117	1.2163	104.398	1.2895	106.924	1.4117	111.136
.030	1.2498	102.035	1.2582	102.316	1.3340	104.842	1.4603	109.054
.031	1.2915	100 087	1.3001	100.368	1.3784	102.894	1.5090	107.106
.032	1 3331	98.261	1.3421	98.542	1.4229	101 068	1 5577	105.280
.033	1.3748	96.546	1.3840	96.827	1 4674	99.353	1 6064	103.565
.034	1.4164	94.932	1 4260	95.213	1.5118	97.739	1.6551	101.951
.035	1.4581	93.410	1.4679	93.691	1.5563	96.217	1.7037	100.429
.036	1.4998	91.972	1.5098	92.253	1.6008	94.779	1 7524	98 991
.037	1.5414	90.612	1 5518	90.893	1.6452	93.419	1.8011	97.631
.038	1.5831	89.324	1.5937	89.605	1.6897	92 131	1.8498	96.343
.039	1.6247	88.102	1.6357	88.383	1.7342	90.909	1 8984	95 121
.040	1.6664	86.941	1.6776	87 282	1.7786	89.748	1 9471	93.960

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Table II.

Reduction of the Scale of Grades (g) to the Scale of Co-officients (c).

Grade, per hundred (g).	Location in Scale of c. $50\sqrt{\frac{1}{g}}$	Grade, per hundred (g).	Location in Scale of c. $50\sqrt{\frac{1}{g}}$
0.040	250.000	0.21	109.110
.042	243.975	.23	104.270
.044	238.365	.25	100.000
.046	233.125	.27	96.225
.048	228.215	.30	91.285
.050	223.605	.35	84.515
.0525	218.215	.40	79.055
.055	213.195	.45	74.540
.0575	208.515	.50	70.710
.060	204.120	.60	64.550
.065	196.110	·70	59.760
.070	188.980	.80	55.900
.075	182.565	.90	52.705
.080	176.775	1.00	50.000
·085	171.495	1.25	44.720
.090	166.665	1.50	40.825
.095	162.220	1.75	37.795
.10	158.110	2.00	35.355
.11	150.755	2.50	31.620
.12	144.335	3.00	28.865
.13	138.665	3.50	26.725
.14	133.630	4.00	25.000
.15	129.100	5.00	22.360
.16	125.000	6.00	20.410
.17	121.265	7.00	18.895
.18	117.850	8.00	17.675
.19	114.705	9.00	16.667
·.20	111.800	10.00	15.800

Flow of Water in Small Channels

Diagram,

(After Kutter)

For obtaining the relations in English measure between

Mean Velocity (v)

Kutter's Coefficients (c)

Mean Hydraulic Radius (R)

Roughness of Wetted Perimeter (n)

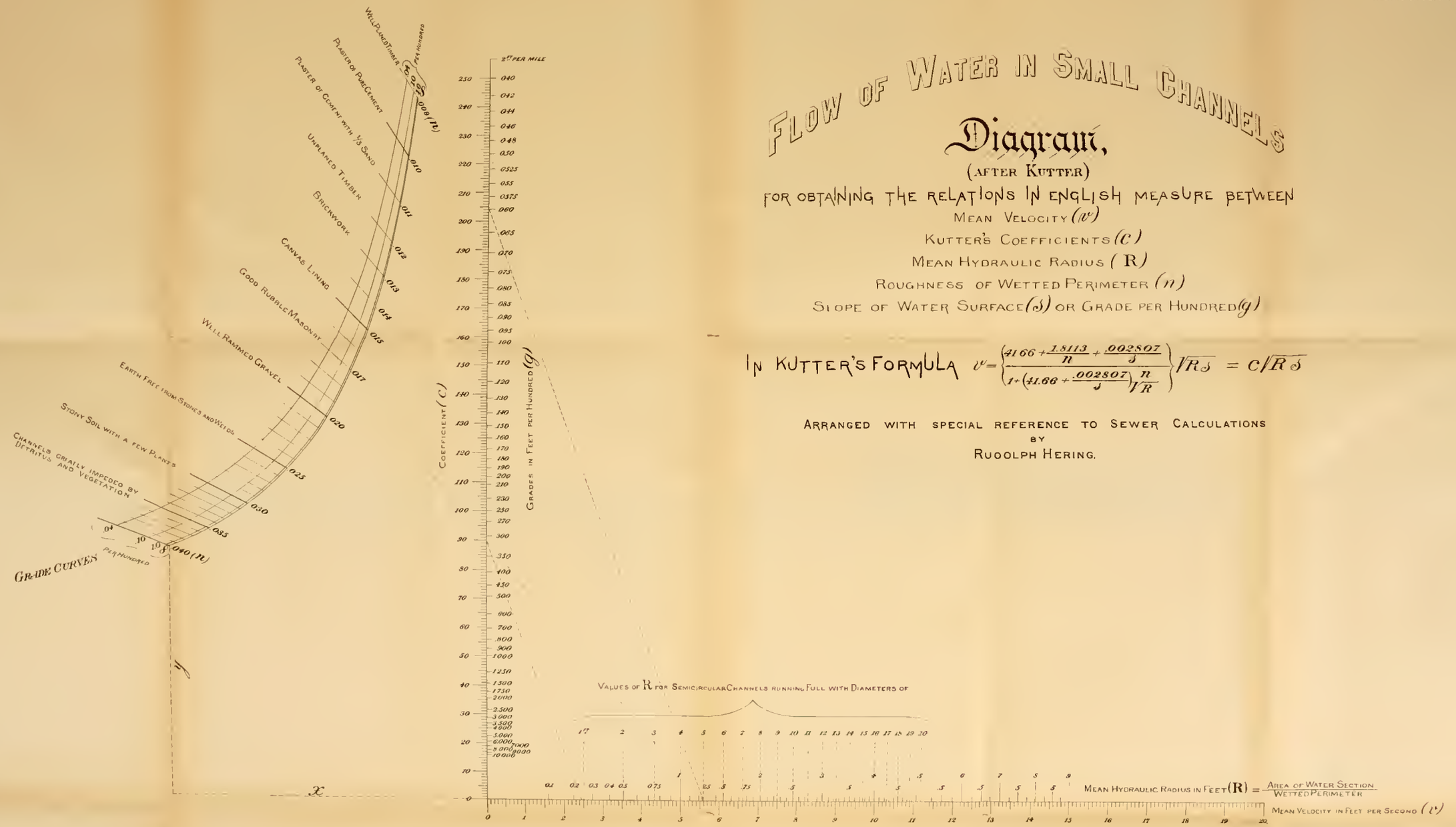
Slope of Water Surface (s) or Grade per Hundred (g)

In Kutter's Formula $v = \left\{ \dfrac{41.66 + \dfrac{1.8113}{n} + \dfrac{.002807}{s}}{1 + \left(41.66 + \dfrac{.002807}{s}\right)\dfrac{n}{\sqrt{R}}} \right\} \sqrt{Rs} = c\sqrt{Rs}$

Arranged with special reference to Sewer Calculations

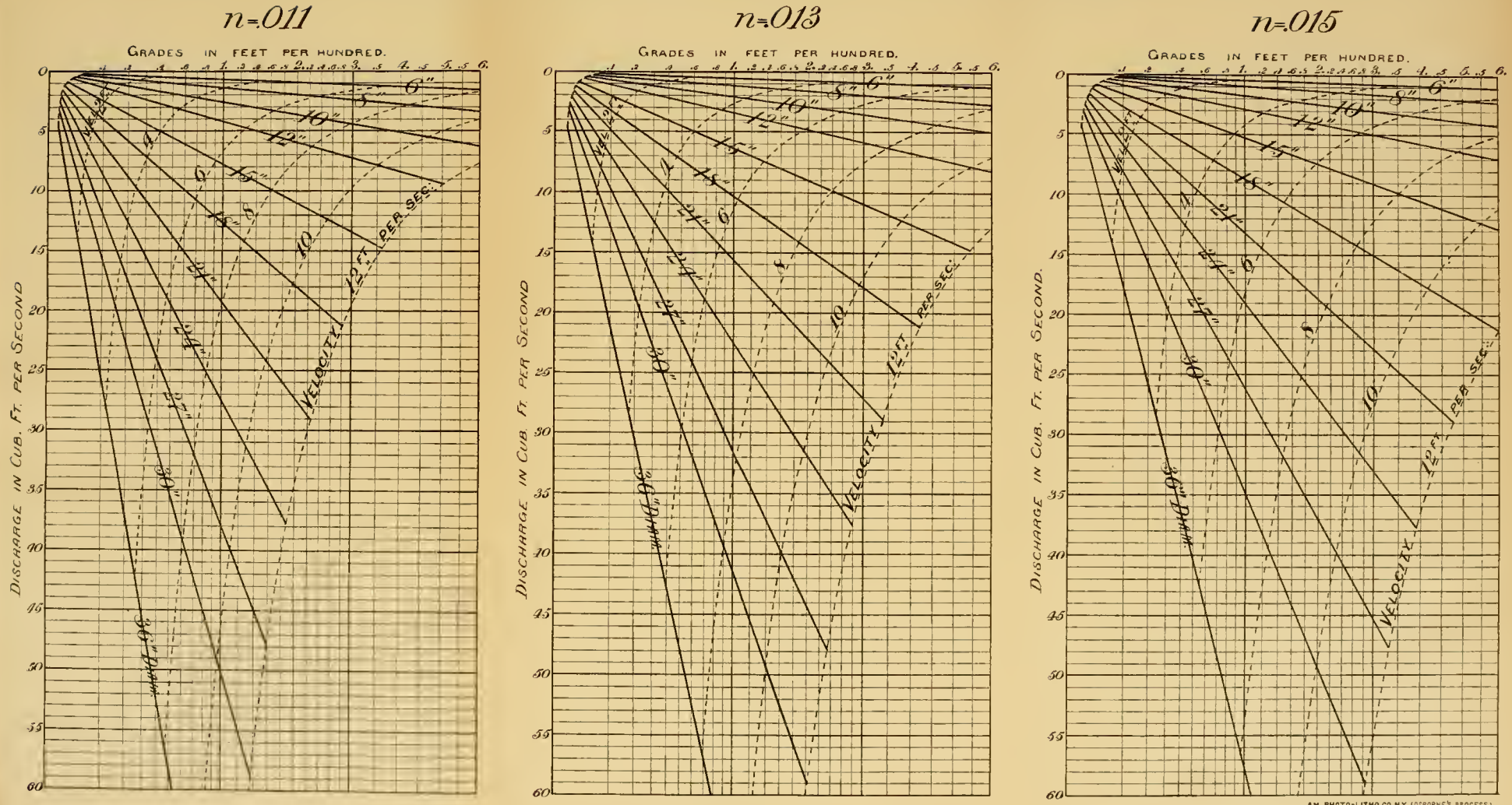
by

Rudolph Hering.



A.M. PHOTO-LITHO CO. N.Y. (BUSHNELL PROCESS)

PIPE SEWERS RUNNING FULL.



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EGG-SHAPED SEWERS RUNNING $\frac{2}{3}$ FULL.

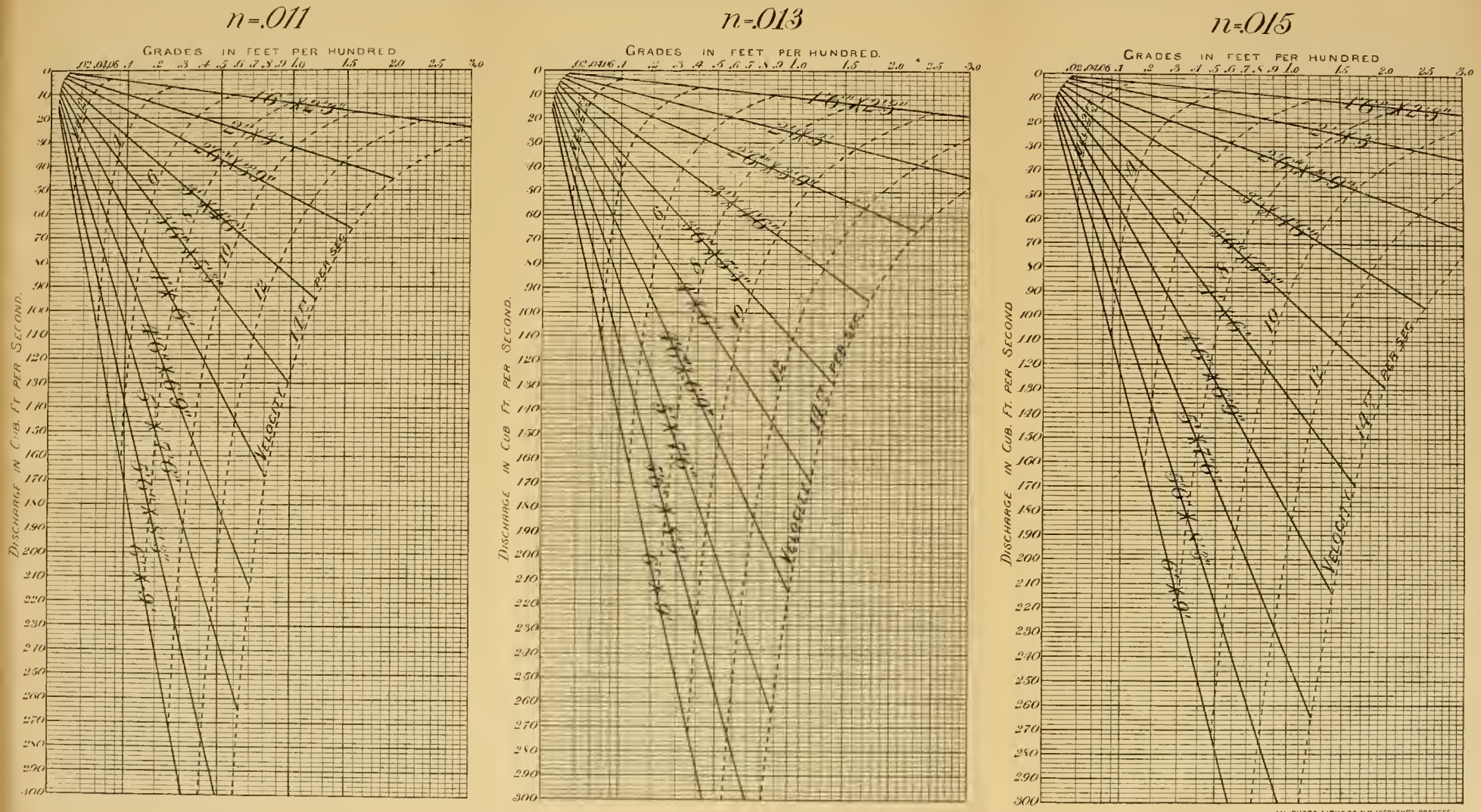

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PLATE IV
TRANS. AM. SOC. CIV. ENGR'S.
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HERING ON FLOW OF WATER.

CIRCULAR SEWERS RUNNING FULL.

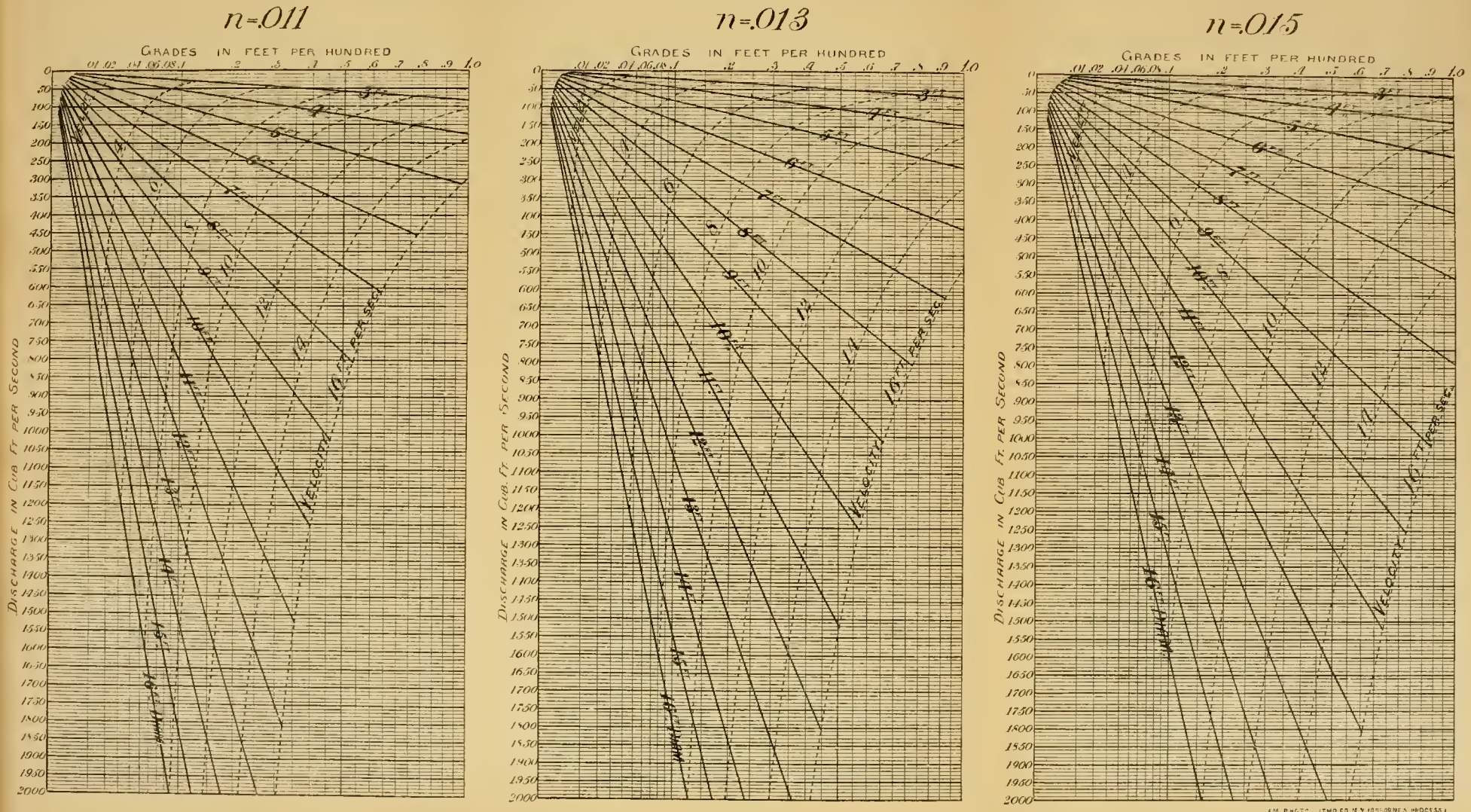
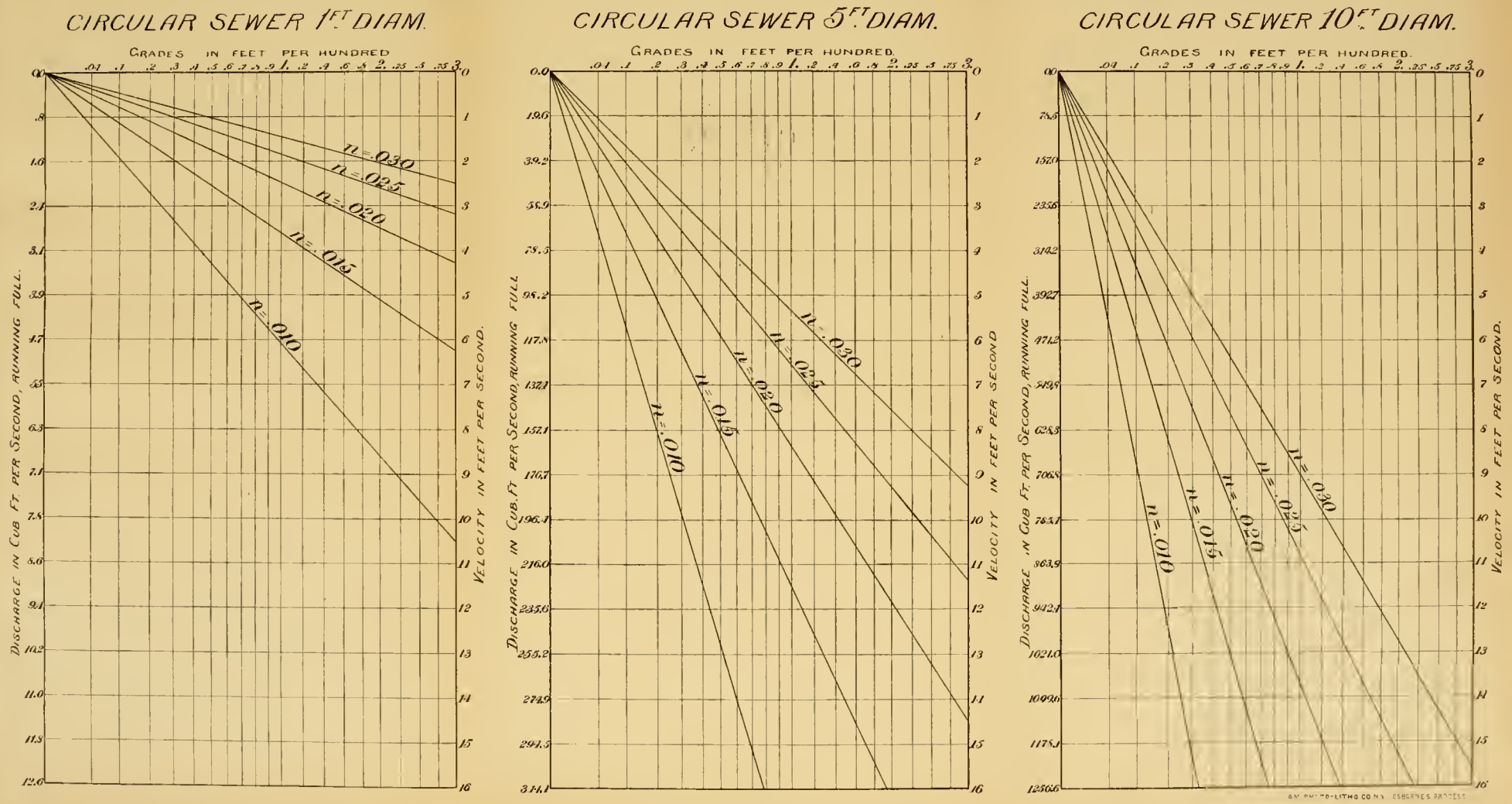


DIAGRAM SHOWING INFLUENCE OF ROUGHNESS.



AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

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CLXXVI.

(Vol. VIII.—January, 1879).

THE PERMANENT WAY OF RAILWAYS IN GREAT BRITAIN AND IRELAND,

WITH ESPECIAL REFERENCE TO THE USE OF TIMBER PRESERVED AND UNPRESERVED.

COMPILED FROM INFORMATION RECEIVED FROM ENGINEERS IN CHARGE OF THOSE RAILWAYS.

By JOHN BOGART, C. E., Member of the Society.

READ NOVEMBER 20TH, 1878.

The comparative economic value, for use in railway construction, of timber preserved and unpreserved, and the best methods for its preservation, have been brought before the Society at various times, and particularly at the Convention in June last. The first cost of wood will probably increase in this country in some proportion to the growth of the population, and the supply of the hard woods now generally used for railroad sleepers* will decrease, particularly in the older States.

* The cross timbers supporting the rails, and which are called *ties* in the United States, are designated *sleepers* in Great Britain. As the latter term is used by the Engineers whose experience is given in the table accompanying this paper, it will be, for convenience, also used by the writer.

The fact was known that the timber used for permanent way in Europe was in many cases treated with creosote oil or other preparations. It was also understood, that by the use of prepared timber, it was possible to employ economically some of the softer varieties of wood. The details of the experience of the European roads did not seem to be very definitely or generally known here, and, therefore, the writer prepared a letter, embodying in a series of questions most of the points upon which superior advantages had been claimed for preserved timber.

This letter was sent to the engineers of a number of the railways in Great Britain and Ireland, and full answers have been kindly returned. Many of the former individual lines of railway have been merged into one or the other of the great companies, and it is thought that these answers represent quite fairly the actual experience upon the subject. These answers are summarily presented in the table accompanying this paper.

Nearly all the lines included in this table use the double headed rail with chairs. In fact, this style of rail seems to be generally preferred wherever the traffic is heavy. Drawings of the rails, chairs and methods of attachment have been kindly sent by the engineers of several railways, and characteristic features are shown in plates VI, VII and VIII, accompanying this paper. A full-sized chair and section of rail, with key, treenails and bolt, attached to a section of a sleeper, have been forwarded by William Jacomb, Esq., Chief Resident Engineer to the London and Southwestern Railway Company, and are now in the Museum of the Society.

Most of the sleepers used in Great Britain are of Baltic red wood, and are generally 8 feet 11 inches, or 9 feet long by 10 inches by 5 inches. The gauge of the roads is 4 feet 8½ inches. The sleepers are generally rectangular. The chairs are attached to the sleepers by combined bolts and oak treenails, or by a bolt alone, generally two to each chair. The general form of treenails is shown in plate VII. They are driven through the chair bolt hole, and into a hole previously bored quite through the sleeper. A smooth round-headed iron bolt is then driven into the opening in the treenail, and forces it tightly against and into the grain of the sleeper. The base of the chair is made of quite large area to avoid cutting the tie. The rail is held in the grasp of the chair by means of a compressed oak key, sections of which are shown in the plates. The weights of the chairs are given in the accompanying table.

On one line, the North Eastern Railway, a cushion of oak is placed under the rail, between it and the chair, as is shown in plate VIII. On this line a twisted bolt is used instead of a treenail and smooth bolt.

The weight of the rails is generally about 80 pounds per yard on the lines having large traffic. The sections of rails shown in plates VI and VIII are of 80 and 82 pounds steel rails. The sleepers are generally quite covered with the ballast, as is shown in plate VI.

It will be seen from the table that the sleepers are treated with creosote oil on most of the lines from which information has been received, and that this method of preservation is the only one now in use. The cost of treating averages about 10½ pence for each sleeper. The amount of creosote oil forced into the wood averages about 0.82 gallons per cubic foot. I am informed by manufacturers that the weight of creosote oil should be 8¾ lbs. to the gallon of 231 cubic inches; the weight of oil forced into the wood therefore averages about 7.175 lbs. per cubic foot of timber.

The life of the creosoted railway sleeper, as shown by the table, varies greatly, owing, doubtless, to circumstances of traffic, drainage, ballast, etc. The average life seems to be about 16 years, and the average gain from preservation is stated at from 2 to 10 years, averaging about 6 years.

Hard woods, as oak and chestnut, are not at all used for railway sleepers.

Samples of sleepers taken from the roadways where they had been in actual use for a number of years have been kindly forwarded to the Society, and are exhibited at this meeting. Some others have been sent, but have not yet arrived. All of these sleepers which are now here are in what seems to be a remarkably good state of preservation after a service of ten, eleven, twenty and twenty-two years. They are not decayed, are very little worn by the chairs, and have only two or three spike or treenail holes.

One sleeper is from the line of the Great Northern Railway, and has been in use from April, 1867, to October, 1877. One is from the London and South Western Railway, and has been in use 11 years. In reference to one from the North Eastern Railway, Alfred Harrison, Esq., the Engineer in charge, writes:

"It is a Scotch fir sleeper, creosoted, and was on July 29th, 1878, taken promiscuously out of half a mile that was laid down in the main line near Tweed-

mouth in June, 1858, thus having been in use for 20 years. I consider them still in a very good condition, and likely to wear other 10 years yet. They have been run over during that time by all through passenger and goods trains between London and Edinbro."

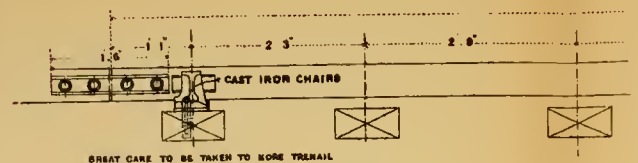
E. H. Lloyd, Esq., Divisional Engineer, sends from the line of the Great Western Railway two creosoted sleepers, and writes:

"I have sent you two sleepers which have been taken expressly out of the line near Swansea, and which have carried the heaviest traffic since the year 1857. You will observe that the sleepers are exceptionally thick and narrow, but notwithstanding these apparent disadvantages they have done their work marvellously well. This I attribute to the fact of the timber being of the very best yellow pine. They were originally 11 feet long, having been laid for the broad gauge, but in 1872, when the gauge of the South Wales line was changed, they were cut to their present lengths. I believe that these sleepers, from the length of time they have been in the line, and the very heavy nature of the traffic which has passed over them during the last 22 years, will prove most interesting instances in the economy of providing timber of the very best quality for railway work."

The writer begs to express his thanks for the full information sent by the engineers whose names are given in the accompanying table, both in replies to questions and in drawings showing the features of the permanent way of the different lines; also for the samples of sleepers taken from the roadbed as described above.

The object of this paper is simply the presentation of the facts obtained from the engineers of railway lines in Great Britain and Ireland. The table which accompanies it gives the answers just as received.

It is presented with the hope that a record of the actual experience of the life of timber in American railways may soon be prepared, and that a discussion may tend towards a solution of the question whether the time has yet come for an economic adoption of preservative processes for railroad timber in this country, upon which question there seems now to be a marked difference of opinion.



NOTE.

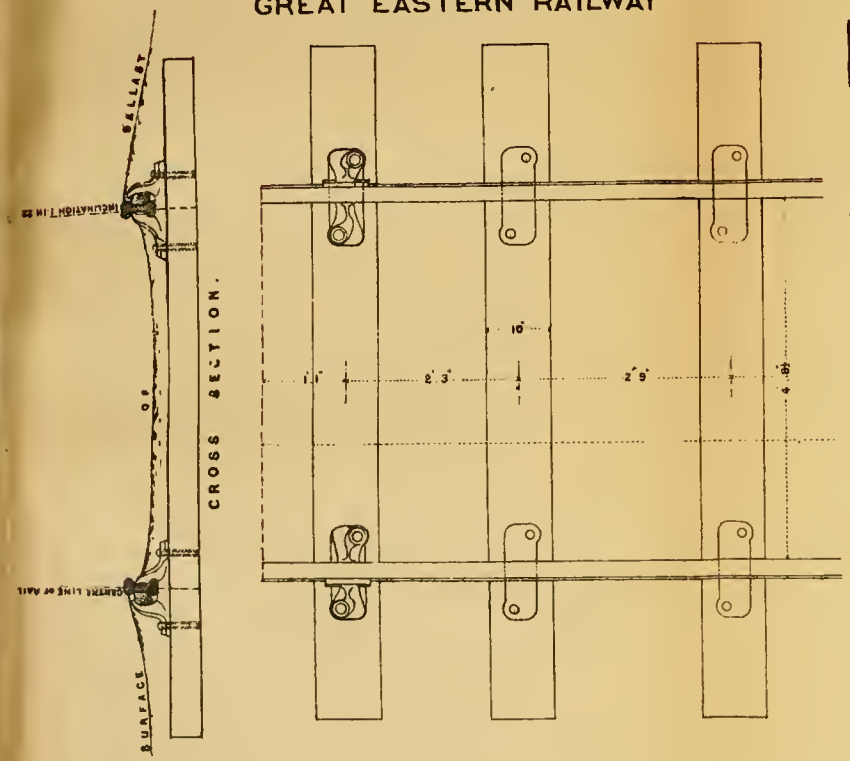
GREAT CARE TO BE TAKEN TO BORE TRENAIL HOLES QUITE THRO' SLEEPER.

TRENAILS, SPIKE, AND THREAD OF FISH BOLTS TO BE DIPPED IN TAR BEFORE USING.

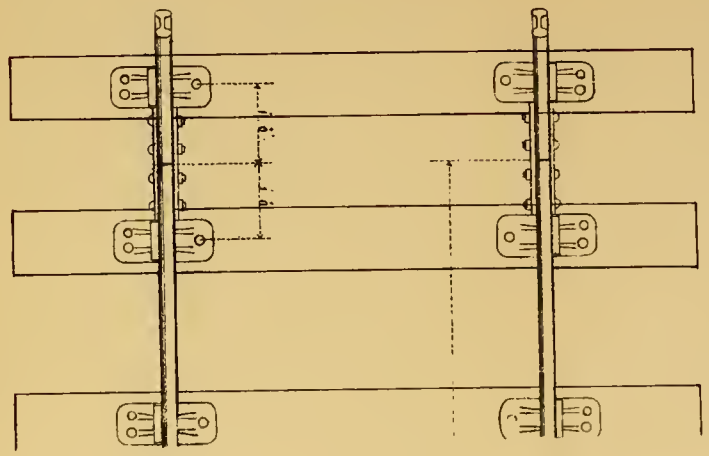
THE KEYS TO BE DRIVEN IN THE SAME DIRECTION, AS THE TRAINS TRAVEL WHENEVER PRACTICABLE.

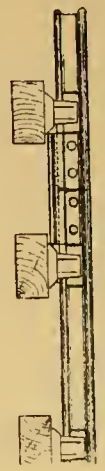
NUTS TO FISH PLATE BOLTS TO BE ON OUTSIDE OF LINE

GREAT EASTERN RAILWAY

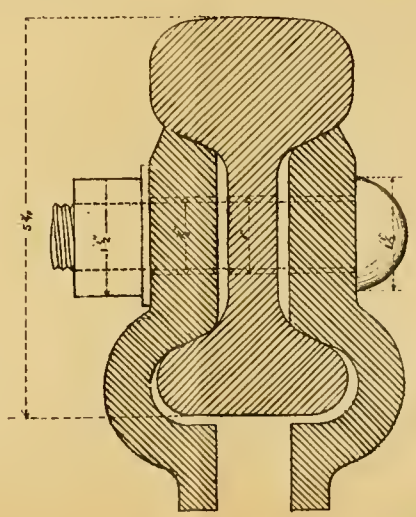


GREAT NORTHERN RAILWAY



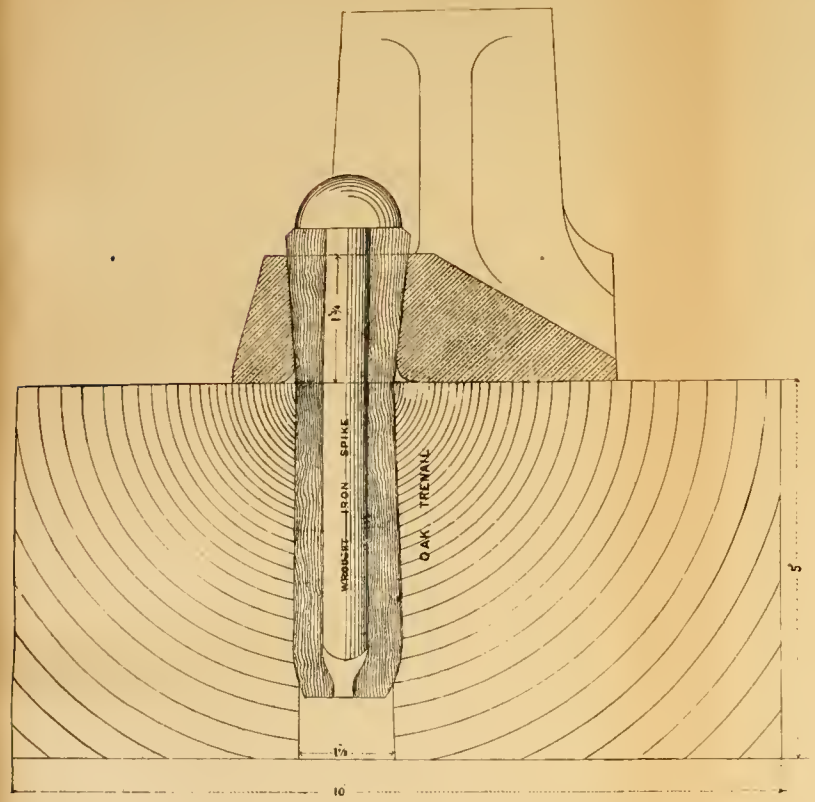


HALF SIZE SECTION OF RAIL & FISH PLATE

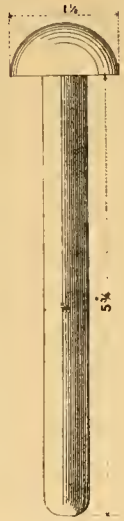


DETAILS OF FASTENINGS.

GREAT EASTERN RAILWAY

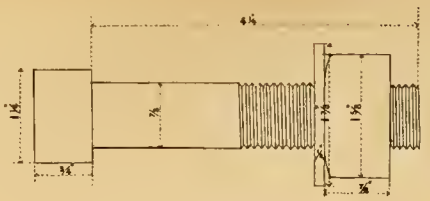


VERTICAL SECTION THRO' TRENAIL

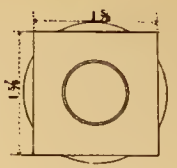


ELEVATION OF SPIKE.

PLAN OF HEAD



ELEVATION OF FISH BOLT.



PLAN OF NUT.

WOOD KEY FOR 80 LBS IRON RAIL.

KEYS TO BE MADE OF THIS SECTION THROUGHOUT

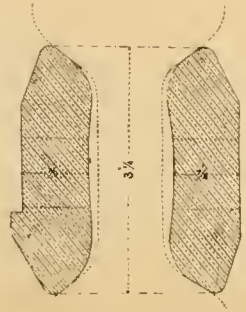
CROSS SECTION.

ELEVATION

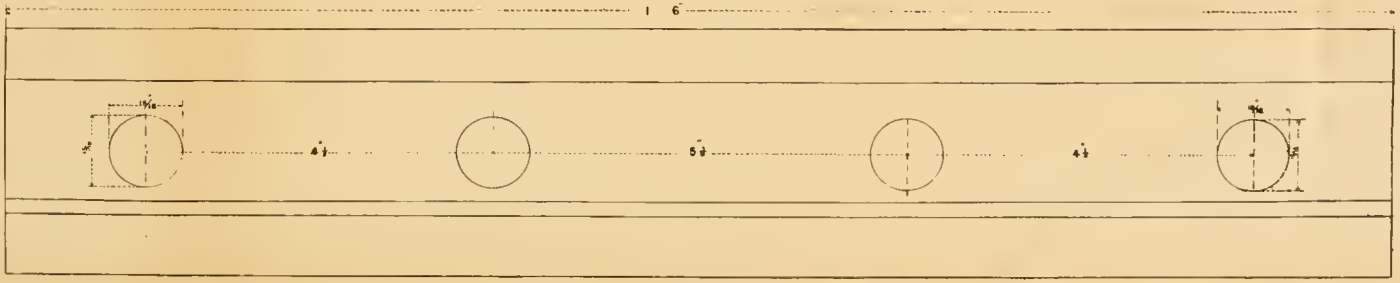
NOTE.
SIDES OF KEY TO BE PARALLEL.

	LBS.	OZ
WEIGHT OF ONE SPIKE		10
PAIR OF FISH PLATES	23	
FISH BOLT, NUT & WASHER	1½	

FISH PLATES FOR 80 LBS RAIL.



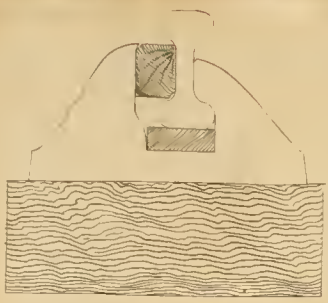
CROSS SECTION.

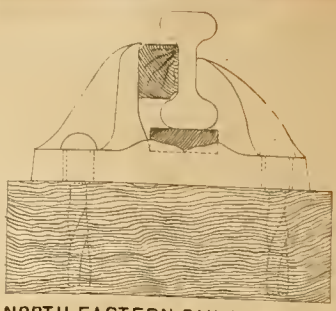


ELEVATION.

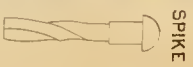
LONGITUDINAL SECTION

FRONT ELEVATION





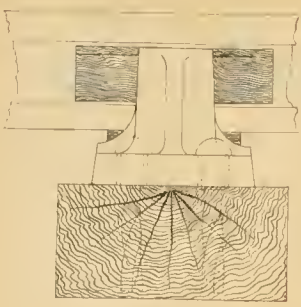
NORTH EASTERN RAIL WAY

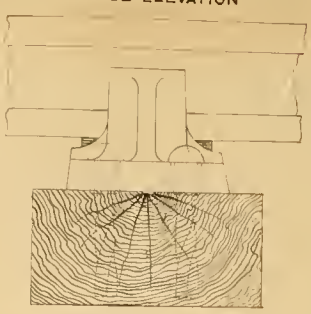


SPIKE

OUTSIDE ELEVATION

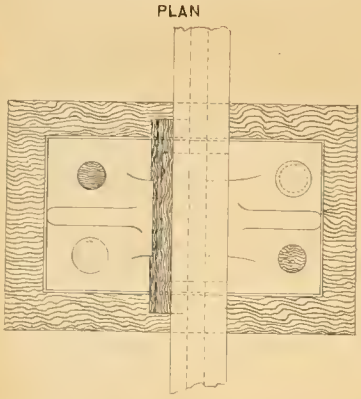
INSIDE ELEVATION

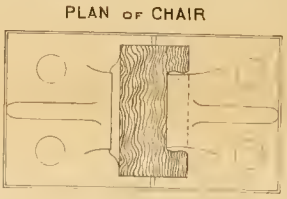




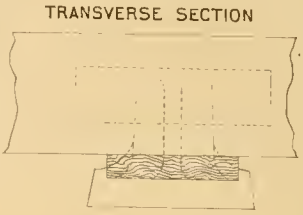
PLAN OF CHAIR

PLAN

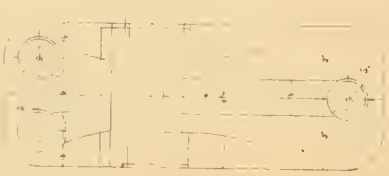


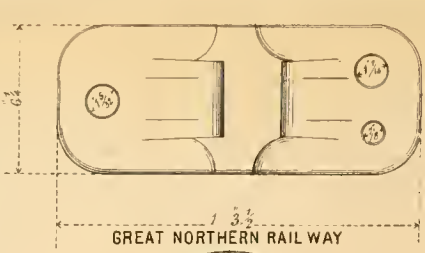


TRANSVERSE SECTION

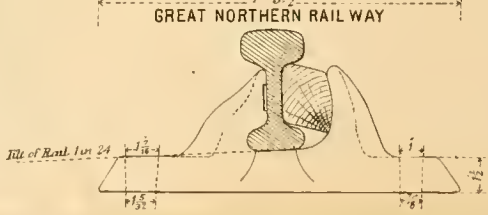


MANCHESTER SHEFFIELD & LINCOLNSHIRE RAILWAY





GREAT NORTHERN RAIL WAY



GREAT EASTERN RAILWAY.

PLATE VIII
TRANSAM. INST. CIV. ENGRS
VOL. VIII. PL. CLXXV
BOGART ON PERMANENT WAY
Scale 1 Foot to 1 Foot

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CLXXVII.

Vol. VIII.—February, 1879.

EXPERIMENTS ON THE RESISTANCES OF ROLLING STOCK.

Made under the direction of CHARLES PAINE, C. E., Member of the Society, by A. M. WELLINGTON, C. E.

The following paper, constituting Mr. Wellington's report to Mr. Paine, formed part of the Report of the Committee appointed by this Society on Resistances of Trains. It was presented at the Twenty-sixth Annual Meeting, November 6th, 1878, and was read January 15th, 1879:

The mode of test was by what may be termed the "drop test;" starting cars from a state of rest down a known grade, and deducing the resistances from the velocity acquired. The principle of this method has

often been employed before, sometimes merely to determine comparative resistances, without attempting to measure their absolute amount, and sometimes to determine a single average resistance from the average velocity for the whole descent. In the present tests, it was attempted with entire success, to extend this method to the determination of a series of successive resistances at successive points (eleven in most cases) in the path of the vehicles, during which their velocity varied from 0 to 30 miles per hour. Great accuracy in time observations was necessary for this purpose, which was fully secured by the aid of electricity, so fully in fact, that the margin for error in the latter half of the experiments is hardly more than 1-10 lb. per ton. It must be added, however, that about half the tests were made before the apparatus was fully perfected, and are, hence, less minutely accurate, but the maximum errors in these latter, can hardly exceed ½ lb per ton in any case, as will be evident from the record plates, and all errors of any kind, in this mode of test, are necessarily compensatory, any excess in one resistance causing a corresponding deficiency in the succeeding one, and *vice versa.*

It is believed that equal accuracy is unattainable by any other mode of test, since it is plain that every step in this process is free from any sensible source of error, other than carelessness. The accelerating force (gravity) is uniformly applied, and exactly known from formulæ, without measurement. This force is neccessarily all consumed (1), in overcoming the resistances to be measured, or (2), in communicating velocity. The amount of force represented by a given velocity is known by formulæ, without measurement, and the velocity itself is exactly recorded by electricity, beside a synchronous record of seconds, from which intervals of time may be easily read off to $\frac{1}{20}$ second. Errors from carelessness in computation are always possible, but three checks existed against them (1), all formulæ used were first tabulated by "constant differences;" (2) Most of the resistances were computed independently by two distinct methods, and (3) all the computations, when completed, were plotted on the record diagrams (Plate IX), and so many resistances were determined for each test at gradually increasing velocities, that any considerable error of computation revealed itself graphically. Finally, any errors which still occur are not cumulative, any excess in one resistance causing a corresponding deficiency in the next following, and *vice versa.*

The mathematical formulæ and other details of the process of computing these resistances, being necessarily somewhat tedious and apart from

the main purpose of this paper, are given in an appended note for those wishing to examine them.*

The tests were made under as great a variety of conditions in respect to load, number of cars in a train, area of cross-section, &c., as it was possible to secure with the limited time at command, and give due certainty to each. This variety of conditions was secured in order to facilitate, as far as possible, one of the objects which was held especially in

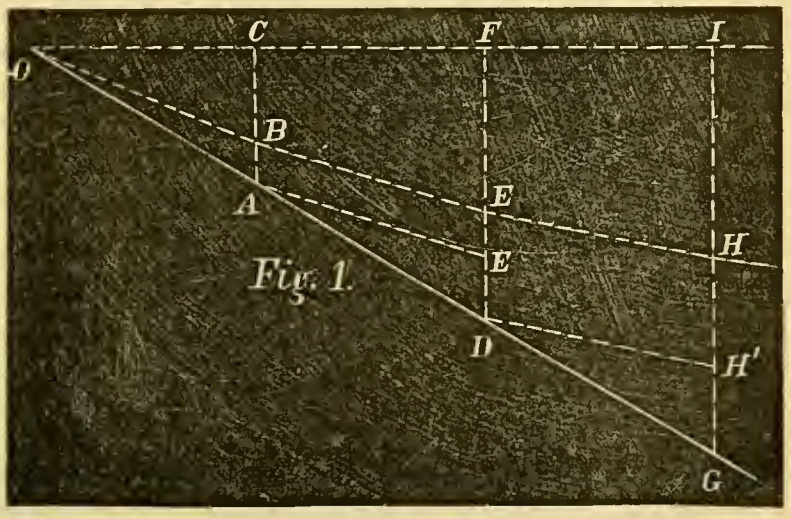
* According to the general law of falling bodies, any body descending freely, *i. e.*, without frictional resistance, over any inclined path whatsoever, as *O A*, Fig. 1, will be moving through space at any point, *A*, in its path with the same velocity as if it had fallen vertically from *C* to *A*. This velocity, for any given fall, *h*, is given in feet per second, by the well-known formula

$$V = \sqrt{gh}$$

in which $g =$ the "acceleration of gravity" $= 64{,}333$.

If the body does not descend freely, but is retarded by certain resistances, a certain portion of the accelerating force will be consumed by these resistances instead of communicating velocity to the body, so that the velocity actually acquired may be made a measure of those resistances.

A car or cars descending a given grade as *O A*, Fig. 1, is under these latter conditions. At any point *A*, in its path it is moving with a certain velocity. When this is known we can readily determine from the formula above, or from a table, the corresponding fall, *C B*, through which it must have fallen freely to acquire that velocity. The residue, *B A*, of the distance through which it is known to have actually fallen, represents the fall necessary to exactly balance the average resistance in passing from *O* to *A*. Then evidently $\frac{B\,A}{O\,C}$ will represent a corresponding rate of grade, which is the "grade of repose," so called; and this rate of grade in feet per 100, multiplied by 20 (*i.e.*, $\frac{2000}{100}$ gives the accelerating force of gravity on the "grade of repose," in pounds per ton (of 2000 pounds) = the total resistance in pounds per ton.



C B, E F, I H,—Velocity Heads or Falls. *A B, D E, G H,*—Friction Heads or Falls.
O A D G,—Actual Grade. *O B E H,*—Equivalent Grade, ex-Friction.

Similarly, if the car continue its motion down the grade to any point, *D*. Fig. 1, and we determine the velocity with which it is moving at that point and the corresponding fall *F E*, necessary to give that velocity, the residue, *E D*, of the distance through which it has actually fallen.

view, viz., a more correct separation than heretofore of the aggregate resistance *from velocity only* (excluding the normal axle friction) into its constituent elements, air resistance, oscillatory resistance, &c. This object, it is thought, has been quite successfully attained, and with somewhat surprising results.

The piece of track selected for the tests was 6,400 feet long, on one of the main tracks of the L. S. & M. S. Ry., about 4 miles west of Cleveland, and on an average grade (from which the variations were very slight) of about .7 per station, equal to 36.5 feet per mile, or to an accelerating force of 14 lbs per ton. In the middle of this distance was a 1°

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will represent the total amount of fall which has been consumed up to that time, by the resistances encountered from the beginning of motion at *O*. But of this distance *E D*, a certain portion, *B A*, had been consumed by the resistances encountered before passing *A*. Consequently, laying off $E\,E' = B\,A$, on the line *E D*, we have *E' D* as the fall, or "head," consumed by the resistances between *A* and *D*; and $\frac{E'\,D}{C\,F}$ = a new grade of repose between *C* and *F*, from which the resistance in pounds per ton can be again determined as above.

Thus we may continue to any extent for any desired number of stations until the car ceases to acquire velocity on the given grade. The "velocity head," *F E*, will then be the same at each station, and the broken line *O B E H*, which might be termed the frictionless grade line (or the grade over which the body would move with the given velocities if there were no friction whatever) will become a horizontal line.

This whole process is strictly analogous to the separation of the fall in pipes, and conduits into "velocity-head" and "friction-head," familiar to all hydraulic engineers.

It is evident that the sole source of error in such computations lies in the determination of the velocity of motion at the instant of passing the various stations, which is done by the aid of electricity. To determine these required velocities two different methods are possible, and most of the present experiments were computed by each independently.

1st. We may determine the velocity DIRECTLY by observing the time in seconds and hundredths required for two fixed points of the train, as the first and last wheel, to pass over each station. Computations made from velocities thus determined are marked in the record-diagrams thus —×—.

This is the most satisfactory and convenient method in experimenting on trains of over five cars, but for shorter trains the method becomes inaccurate at high velocities.

By this method the average resistance between two points is given exactly, however rough and irregular the track and however broken the grade.

2d. We may compute the initial and terminal velocities at the successive stations from the average velocities between them by a formula deduced from the known laws of falling bodies, as follows;

If any body be descending freely by its own weight, its velocity at any instant is directly as the square root of the space fallen through. Consequently if we have two or more points, as 10, 15, 20, &c., Fig. 2, along the path of any such body, and know the distances, say 10, 15, 20, &c. of each from the point *O* at which it started, the velocity of motion at 10 ($= V_{10}$) will be

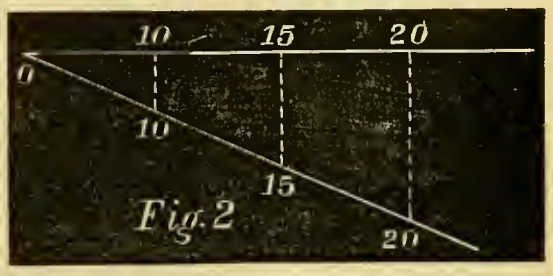

Fig. 2

$\sqrt{\frac{10}{15}}$ of that at 15, and *vice versa*, the velocity at 15 ($= V_{15}$) will be $\sqrt{\frac{15}{10}}$ of that at 10.

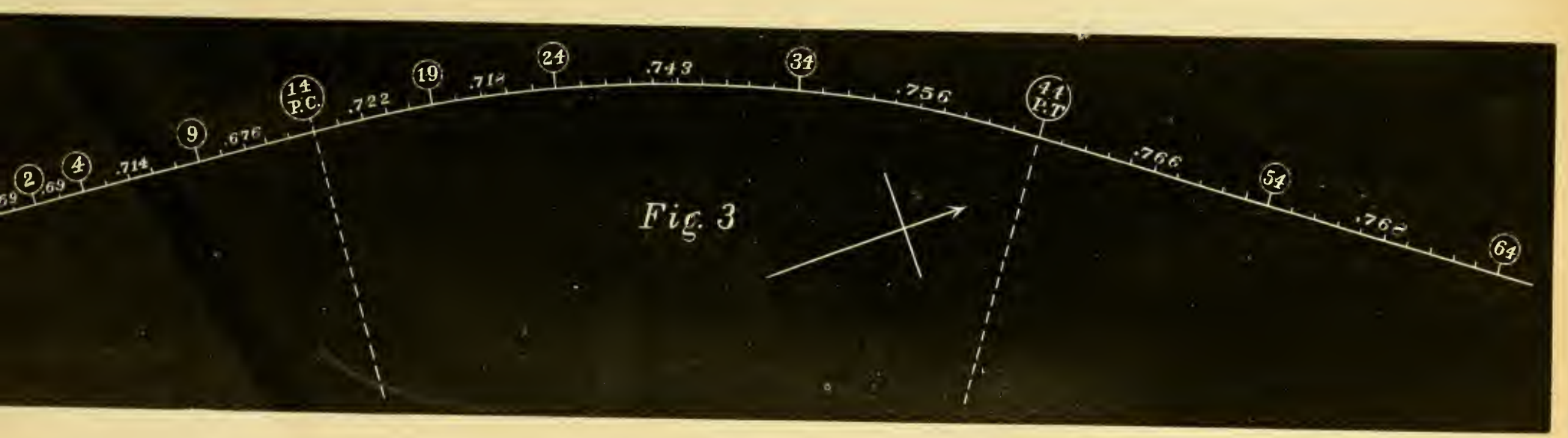

Fig. 3

Figures in circles show the stations at which observations were taken, the starting point for all tests being 0. The figures also show the distance of each station from the starting point, in hundred feet. Decimals between stations show the average rate of grade per 100 feet.

curve (5,730 feet radius), 3,000 feet long. as shown on Fig. 3 herewith, which also shows some further notes of the elevations, observation stations, &c. The rails were iron, 60 lbs. per yard, and the track was well ballasted and in good line and surface, but not strictly first-class. Levels were carefully taken on each rail at each 100 feet station, and the differences of elevation shown on Fig. 3, are for the centre line of the track. The elevation of the curve varied from 3 to 4 inches,

Tests were made on six different days during the summer, the average temperature being 75° (varying from 69° to 82°), and the average velocity of the wind, according to the records of the Signal Service, about 8 miles per hour. The test-track, however, was mostly in a long cut, and well sheltered by trees, and in no one of the tests—excepting four or five which have been thrown out on that account—was there any wind perceptible to the senses at the starting point *O*, Fig. 3, where the telegraph instruments were located.

The stations at which time-records were taken off, varied from 200 to 1,000 feet apart, as shown in Fig. 3. A telegraph line was erected on fence posts, and connected with a circuit-breaker at each of these stations, in such manner that the passage of each wheel of the train over the station would break the circuit. These circuit-breakers were improvised from the patent spring clothes-pins familiar to almost every one, and were placed along the outside of the rail, in the manner shown in Fig. 4. An ordinary Morse registering instrument was attached to this circuit, which fed the paper strip at the rate of about one-half inch per second, and it will be evident that the passage of a wheel over any one of these

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Moreover, the *average* velocity ($= V_a$) between any two stations on the path of a body acted upon by a uniform accelerating force (as when falling freely or on a straight grade) is always equal to the half sum of the initial and terminal velocities at those stations. Then from these data we have—

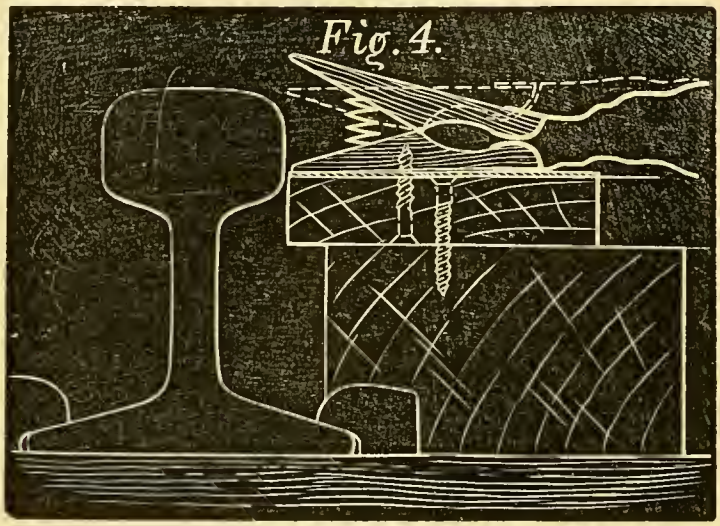
$$V_{10} = 2\,V_a - V_{15} = \sqrt{\frac{10}{15}}\,V_{15}$$

Thence
$$V_{15} = \frac{2\,V_a}{1 + \sqrt{\frac{10}{15}}} \qquad (2)$$

And
$$V_{10} = \frac{2\,V_a}{1 + \sqrt{\frac{15}{10}}} \qquad (3)$$

The formulæ above determined (2) and (3), are not strictly correct when applied to the motion of cars, because they assume that the train as acted upon by a *uniform* accelerating force, whereas in fact it is a force constantly decreasing with the increase of velocity and resistance. But the error in practice is not important. If the formulæ were strictly correct,

stations would leave its record on the paper, as if it were part of an ordinary telegraphic message.



A synchronous time record was obtained by adding another armature and recording point to the instrument, connected with a separate circuit, in which a seconds pendulum was inserted, breaking the circuit at each vibration.

Two simultaneous records were thus placed upon the paper : 1st, alternate dashes and blanks, representing half a second each, by the circuit connected with the seconds pendulum ; and 2d, a record of the passage of each wheel over each station, by the other and main circuit. Plate XI shows the record thus obtained in Test No. 48, of the sleeping coach "Chicago," fitted with the Higley patent roller journals. Tests Nos. 47, 48 and 49, were made one after another, with the same car, with this apparatus ; and it will be seen on Plate IX, how closely they correspond. The apparatus has since been somewhat improved by bringing the two synchronous records nearer together than shown in Plate XI. But even in the form there shown, it is possible to read the record within .01 to .03 seconds by constructing a suitable scale.

In addition to the telegraphic record, the time at each station was carefully taken by an observer with a horse timer or stop watch. Inaccuracies, however, will creep in, in such readings, and as there are no means of locating them, watch-readings are very unsatisfactory by themselves, though useful as a check.

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it is obvious that the *terminal* velocity computed for any one station, as 15, Fig. 2, should correspond with the *initial* velocity at the same station as deduced from the next following average velocity, as between 15 and 20. In practice these two determinations of a single velocity are not the same, but differ from each other by a small, constant amount, and an average between them is taken, as shown in Table I.

Table I.

Computation of Resistances for Test No. 48, Sleeping-Coach "Chicago," fitted with Higley Patent Roller Journal.

Telegraphic Notes of Tests Reproduced in Plate XI.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Station.	Time Record between Stations. Seconds. Watch Time.	Telegraphic Record.	Average Velocity in feet per second.	Initial and Terminal Velocities at each Station. Computed from Average Velocities by Eqs. (2 and 3).	Averages of Initial and Term. Vels., being Vel. at each Station in ft. per sec.	Corresponding fall to give this Velocity = Velocity Head in Feet.	Differences of Velocity Heads in Col. 7.	Actual fall between each Station. Feet.	Friction Head = differ'e between total fall and Vel. fall (Cols. 8 and 9). Feet.	Corresponding rate of grade per Station = grade of repose in feet per Station.	Corresponding Resistance in lbs. per ton = rate of Grade Cols. 11 × 20.
	Secs.	Secs.									lbs.
2.....	48	47.7	4.17	Ter. 8.34 In. 8.14	8.24	1.05	1.05	1.38	0.33	0.165	3.3
4.....	20½	20.2	9.90	Ter. 11.64 In. 11.56	11.60	2.09	1.04	1.38	0.34	0.17	3.4
9.....	34¼	34.6	14.45	Ter. 17.34 In. 17.00	17.17	4.58	2.49	3.57	1.07	0.214	4.28
14 P. C..	26	26.2	19.08	Ter. 21.20 In. 20.6	20.9	6.8	2.22	3.38	1.18	0.236	4.72
19.....	22¼	22.4	22.32	Ter. 24.0 In. 23.4	23.7	8.7	1.90	3.63	1.73	0.346	6.92
24.....	19¾	20.1	24.88	Ter. 26.34 In. 25.66	26.0	10.5	1.80	3.59	1.79	0.358	7.16
34.....	35¾	35.6	28.09	Ter. 30.54 In. 29.92	30.23	14.2	3.70	7.43	3.73	0.373	7.46
44 P. T	31½	31.3	31.95	Ter. 34.00 In. 32.2	33.1	17.1	2.90	7.56	4.66	0.466	9.32
54.....	29½	mis'd	33.90	Ter. 35.6 In. 35.0 (Estimated.)	35.3	19.4	2.30	7.66	5.36	0.536	10.72
64....(Telegraph failed to work).....								7.68			

Remarks.—The "terminal" velocity at Station 2 given in Col. 5 is equal to twice the average velocity, or 4.17 × 2 = 8.34. The remaining velocities in Col. 5, marked "terminal" and "initial" respectively, are computed from each average velocity (in Col. 4) by Eqs. (2) and (3). The two computed velocities at each station shown in Col. 5 should in theory be identical; the difference is due to the constantly increasing resistance as explained in the foot-note to page 22.

If these velocities at each station be recomputed under the strictly correct assumption, viz: that they are proportional to the square root of the velocity head shown in Col. 7, the velocities in Cols. become identical with each other and the same as the average shown in Col. 6, within .02 to .05 feet per second; an error so small as to be of no sensible moment.

The above computation is made from the time occupied in passing from station to station. In addition to the above, a separate determination of the velocity at stations (given in col. 6) was made, in most cases, by reading off from the telegraphic record the time occupied by the train in *passing over* the station, The remainder of the computation was the same as above.

Table I, shows one (and the most complicated) method of computing the resistances for Test No. 48, from the telegraphic notes reproduced in Plate XI. As explained in the foot note to the table, the same resistances were, in most cases, independently computed from the same telegraphic notes by another method. The difference between the two methods, as has been explained in the foot note to page 22, consists simply in the manner of determining the velocity at stations, viz. (*a*), as in Table I, by computation from the average velocity between stations, and (*b*) by a direct reading from the telegraphic record of the time (in seconds and hundredths) occupied by the train in passing over it.

Upwards of 100 tables similar to Table I, have been computed during the tests, the results of which will be found plotted on the accompanying record-diagrams (Plate IX), a few excepted, which were excluded on account of wind resistance or other sources of error. In constructing Plate IX, the velocities are laid off along the horizontal axis, and the corresponding resistances laid off as ordinates. The broken line connecting the points thus obtained, has the general outline of a parabola, its continuity being interrupted, however, first, by the additional resistance of the long curve in the middle of the test-track, and secondly, by two seeming errors in the initial resistances which have a meaning of their own, as explained hereafter.

To generalize the results of the experiments, each test or set of tests, as recorded on the record diagrams (Plate IX), was first formulated, as follows: It was assumed—following after D. K. Clark, and most modern authorities—that the equation of resistance has the form

$$R = f\,V^2 + C. \qquad (4)$$

in which R=the total resistance, V=the velocity in miles per hour, and C=the constant (axle) friction independent of velocity.* Two or more points were selected on the record diagrams at about the highest and about the lowest velocity of each test or set of tests, and the corresponding values of R and V, as read off from the diagram, substituted in equation (4) above. Having thus, for each test, two or more equations of resistance at different velocities, the corresponding values of f and C were deduced by ordinary algebraic processes, and are recorded in Table

* Recent experiments render it highly probable that the axle friction proper may decrease with the velocity of rotation, as, indeed, appears likely from the present experiments. The effect of any probable fluctuation of this kind, however, could hardly be very great upon deductions made under the general formula above. Its effect, if considered, would be to increase the estimate of the velocity-resistance, and all this increase would be confined to that portion of the latter due to oscillation and concussion.

II below. *A* value of *C* (the resistance independent of velocity) was also read off directly from the diagram, immediately after the initial friction (which proved to be unexpectedly great, as will appear below), had disappeared, and excluding its effect. These values appear in the first column of Table II below.

Having explained, as concisely as possible, the process of determining the resistances we may proceed to the results of the experiments.

Axle Friction.

Three singular facts in regard to axle friction are visible in Table II. The first and most striking of these is the very heavy difference in the axle and rolling friction of loaded and empty cars. None of the empty car tests fluctuate far from 6 lbs. per ton ; none of the loaded car tests fluctuate far from 4 lbs. per ton, as is more clearly evident from the following :

Table III.

Showing Differences of Axle Friction in Loaded and Empty Cars.

Empty Freight Cars.			Loaded Freight Cars.		
	Observed Axle friction at 3 to 5 miles per hour.	Computed Axle friction at high velo. from Eq. (4).		Observed Axle friction at 3 to 5 miles per hour.	Computed Axle friction at high velo. from Eq. (4).
Average of 1 empty car tests.....	6.75 lbs.	6 25 lbs.	Average of 2 loaded car tests.....	4.25 lbs	4.1 lbs.
Average of 2 empty car tests.....	6.25 "	6.45 "	Average of 3 loaded car tests.....	4.2 "	3.87 "
Average of 5 empty car tests.....	5.9 "	5.4 "	Average of 5 loaded cars tests.....	4.25 "	3.80 "
Average of all empty car tests.....	6.30 "	6.00 "	Average of all loaded car tests.....	4.18 "	3.92 "
Passenger Rolling Stock (load per journal about the same as loaded freight cars)....			4 coaches separately....	4.37 "	3.67 "
			4 " together.....	3.80 "	3.50 "
			2 " separately...	4.55 "	4.40 "
			2 " together.....	4.00 "	3.60 "
				4.18 "	3.79 "

In support of these very low resistances for loaded stock, it may be added that Mr. J. W. Cloud, assistant in charge of the Test Department of the Pennsylvania Railroad, informed the writer in November of last year,

that he had habitually, or at least usually, found that the resistances of loaded coal cars at 10 to 15 miles per hour was about 4 lbs. per ton *in all.* This would indicate an axle friction proper of not more than 3½ lbs. per ton.

Mr. Cloud has an excellent dynamometer car with a positive spring motion, affording no chance for error from friction of the moving parts of his apparatus, and with the provisions for a synchronous register of velocity which are absolutely essential to make dynamometer tests of any worth.

The second curious fact to be noted in Tables II and III, is that in every instance, with two slight exceptions, the axle friction deduced from comparisons of the high-velocity resistances is less than that observed at low velocities *after* the heavy initial friction has apparently been overcome. The decrease averages 0.3 lb. in the case of freight cars, and 0.4 lb. in the case of passenger cars, and it appears to be an indication of the general law of friction, that the co-efficient decreases with the velocity. It may be, however, merely an indication that the velocity-resistances vary as $V^{2\cdot1}$ instead of V^2. Such a modification of the formula (eq. 4) would amply account for the phenomenon.

Finally, Tables II and III, bring out another curious fact which can hardly be accidental. It will be observed that the axle friction proper (excluding velocity resistances) of a train of cars appears to be less than for the same cars coupled together; and this is the case in both the computed and observed axle friction, as follows:

Difference in Axle Friction, between—	In observed axle friction at low velocities.	In computed axle friction at high velocities.
2 car and 5 car tests, freight cars.....	0.26 lbs.	0.60 lbs.
4 passenger coaches, together and separately.	0.57 "	0.17 "
2 " " " "	0.55 "	0.80 "
Average apparent reduction from coupling cars together.	0.45 "	0.53 "

The horse-cars tested, it will be observed in Table II, show an average axle friction of 10.25 lbs. per ton, the load per wheel being, as nearly as may be, 1 000 lbs. The horse-car wheels were 30 inches in diameter and the journals 2½ × 6. The phenomenon of a decrease

of axle friction with increase of speed is not visible in the horse-car tests.*

Resistance at Starting.—An object especially held in view in beginning these experiments, was to determine how great was the additional friction in *starting* trains which is well known to exist, and how long it continues after getting under way. It has proved to be unexpectedly great, amounting, in most cases, at the instant of starting, to four or five times the normal friction in motion.

The grade at the point of starting was equivalent to an accelerating force of 14 lbs. per ton. Nevertheless, it was necessary, *in almost every instance*, to use the full force of two to six men to start one or two cars after they had been standing from two to ten minutes. Estimating the pushing force per man at 100 lbs., this is equivalent to from 5 to 15 lbs. per ton *in addition* to the 14 lbs. due to gravity as the power required at the instant of starting, after a short stop.† The lowest initial resistance observed in any of the tests was that the cars would start off by a little persuasion such as jarring them more or less, without the application of appreciable force. In other cases, however, it was impossible to start the cars at all without "pinching" under the wheels with a bar, or even touching them with an engine. When the stop was merely instantaneous (in fact, probably not a full stop at all), the initial resistance was very much less, as will be seen in Tests 59–62 on the record diagrams, and the *very great* increase of resistance appears to be almost wholly instantaneous and hence consumes an inappreciable number of foot-pounds. That it is not wholly so, however, was fully apparent, as follows:

The initial impulse communicated as above (in all cases made as little as possible) amounted to from 600 to 1 600 ft.-lbs. per car, which would have the effect to reduce the average resistance from 3 to 8 lbs. per car in a distance of 200 feet, or from .15 to .40 lbs. per ton. But the records the cars show that notwithstanding this extraneous accession of force, clearly were still affected by an abnormal *retarding* influence in the first 200 feet of their run, which greatly increased the resistances over the next following 200 feet.

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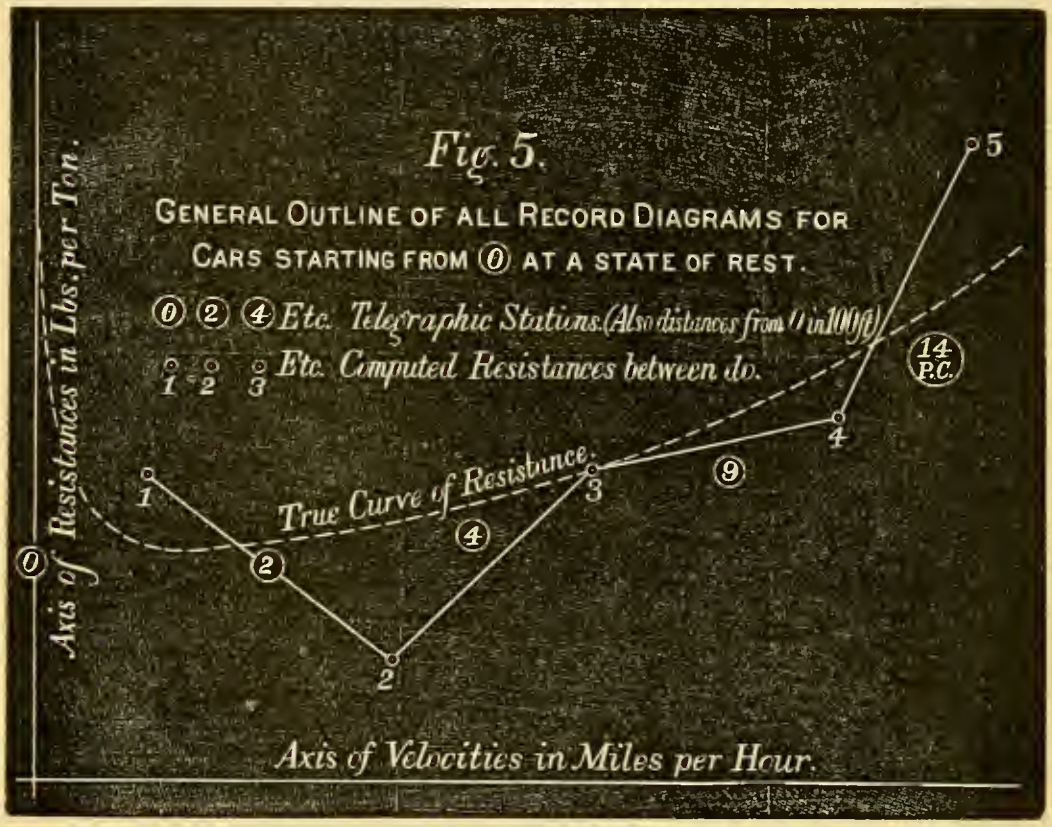
* Mr. Chas. E. Emery, in detailing a horse-car test with a dynamometer interposed between the car and the horses, states (Trans. Am. Soc C. E., Vol. VII., p. 105, April, 1878) that, after eliminating the effect of velocity so far as possible, he determined the resistance to be 11.8 lbs. The coincidence is close and the difference, perhaps, merely represents that portion of the velocity resistance which Mr. Emery could not eliminate.

† It was, of course, determined by trial that this increase was not due to special conditions of track or wheel at any one point of starting.

It is somewhat difficult to explain the nature of this evidence concisely, but it is proved by the abnormally low resistance determined between stations 2 and 4 for almost every one of the tests, as shown on the record-diagrams (Plate IX). Fig. 5 shows the general outline of



Explanation.—Resistance 1 is abnormally increased and resistance 2 abnormally decreased by an irregularity in velocity caused by the high initial resistance shown by the "True curve of resistance." Resistance 3 is unaffected by these irregularities and presumably correct. Resistance 4 is also unaffected by any known source of error, other than a superelevation of one rail, which appears the only explanation for the abnormal depression. Resistance 5 is on the 1° curve, and hence abnormally high.

these record-diagrams, and the true cause of the peculiar depression in "resistance 2"—which appears to be merely an error—is fully explained by Table IV, with its accompanying foot-notes. It will only be added here, that the apparent error is due solely to the fact that the observations were not taken frequently enough between stations 0 and 2 to develope the true form of the curve of resistance, as shown on Plate X.

The telegraphic record furnishes a direct method of proving the correctness of this explanation, by proving the persistence of a high initial resistance for at least one car-length after starting; as follows:

Table V.

Computation from Telegraphic Record (given in Plate XI) of Initial Resistances while moving the first car-length, Test 48, Sleeper "Chicago," fitted with Higley Roller Journal.

1.	2.	3.	4.	5.	6.	7.
Stations.	Time in seconds	Velocity in feet per second.	Fall to give this Velocity. $h = \frac{V^2}{g}$	Difference of Do.	Rate per Station of 100 feet giving "velocity grade."	Do. substracted from .70 (actual rate of grade) giving rate of "friction grade" or "grade of repose."
Front Truck.						
0 feet (1st wheel at Station 0)						
5.33 feet (2d wheel at Station 0).....	5.40	$\frac{5.33}{5.40} = 0.99$	.015 feet.	.15	$\frac{.015}{.030} = .50$	.20 = 4.0 lbs. per ton.
10.67 feet (3d wheel at Station 0)	3.16	$\frac{5.33}{3.16} = 1.70$	.045 "	.030	$\frac{.030}{.0533} = .533$	.167 = 3.34 lbs. per ton.
Rear Truck.						
48.56 feet (1st wheel at Station 0)						
59.23 feet (3d wheel at Station 0)	2.49	$\frac{10.67}{2.49} = 4.29$	.286 "	.41	$\frac{0.241}{.459} = .524$	.176 = 3.52 lbs. per ton.

Explanation.—Column 2 gives the time, in seconds, required for the successive wheels to reach station 0, the car being started with the front wheel of the front truck almost upon it. This time in seconds ÷ the distance between wheels gives the average velocity in feet per second between the time when the successive wheels reached station 0. This average velocity is *assumed*, for simplicity, to be that with which the car is moving at a point midway between the stations marked off by the successive wheels (the effect of this erroneous assumption being only to decrease the apparent initial resistance). Columns 4 and 5 explain themselves, being similar to those shown in Tables I and II. Column 6 gives the "velocity grade," *i. e.*, the quotient of any given "velocity-head" or "fall" divided by its corresponding distance or length of station; and this "velocity grade," substracted from the actual grade per station, gives the "friction grade" per station, from which lbs. per ton are readily deduced.

This method becomes more accurate in proportion as the number of wheels in the car or train is greater. It assumes that minute irregularities in wheels and rails, which would vitiate such computations for a single axle, will balance each other in a considerable number.

Since the law of the acceleration of gravity is true for all falls, we may apply it to very minute distances when the car is moving so slowly that the velocity in falling through them may be measured with sufficient exactness; and we may thus determine three or four different resistances for the period of time during which the car is moving the first car length. To illustrate this a calculation is added in Table V of the initial resistances of the sleeper "Chicago," Test No. 48, while

Table VI.

Co-efficients of Journal Friction.

Size of Journals, $3\frac{1}{4}$ in. x 6 in., horse-car journals, $2\frac{1}{2}$ in. x 6.
Size of wheels, 33 in., " wheels, 30 in.

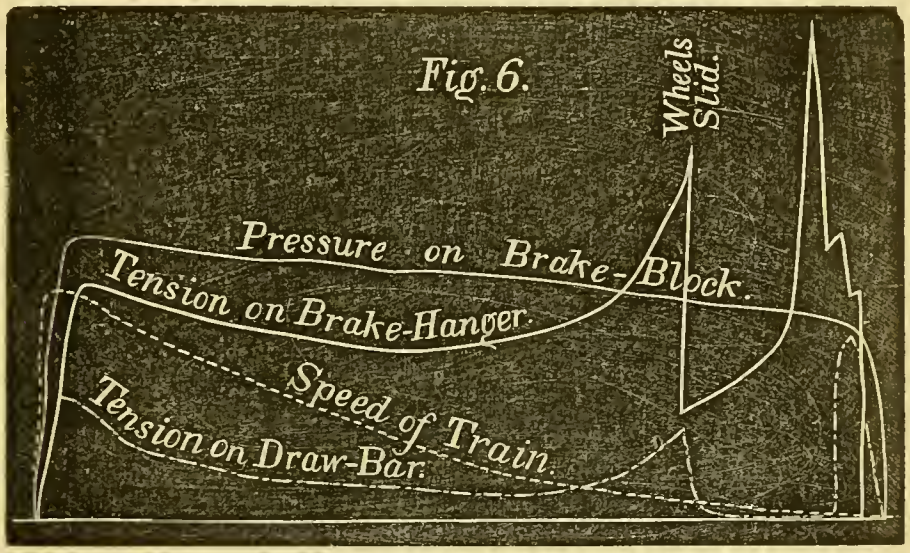
Class of Car.	Conditions.	Load on Journal.		Co-effs. of Fric.		Do. by Prof. Thurston's Expts. W. Va. Oils.
		Total tons.	Per sq. in. lbs.	Formula.	Co-eff.	
Loaded freight and pass'r	At instant of starting.....	2.4	320	$\frac{18 \text{ lbs.}}{2\,000} \times \frac{33}{3\frac{1}{4}}$	.09	.145
" " "	"150′ per min. jour. speed	"	"	$\frac{4 \text{ lbs.}}{2\,000} \times \frac{33}{3\frac{1}{4}}$	.02	.007
Empty freight.....	"instant of starting.....	0.8	170	$\frac{14 \text{ lbs.}}{2\,000} \times \frac{33}{3\frac{1}{4}}$	.07	.135
" "	"150′ per min. jour. speed	"	"	$\frac{6 \text{ lbs.}}{2\,000} \times \frac{33}{3\frac{1}{4}}$	.03	.015
Passenger trucks.....	" " " "	0.45	46	$\frac{8.86}{2\,000} \times \frac{33}{3\frac{1}{4}}$	.045	.024
Freight "	" " " "	0.2	27	$\frac{14.5}{2\,000} \times \frac{33}{3\frac{1}{4}}$	.07	.03
Horse-cars, empty.....	" " " "	0.5	67	$\frac{10.25}{2\,000} \times \frac{30}{2\frac{1}{2}}$	.06	.02

Remarks.—Recent experiments by the writer since completing this paper show that the heavy resistances at the "instant of starting" are not due to that fact *per se*, but to the *infinitesimal velocity* at that instant. If the velocity continue infinitesimal, however long, the excessive resistance still continues. An abstract of these experiments will be published shortly.

moving the first car length. Resistances obtained in the same manner will be found plotted at the left of several of the record diagrams, and show very great initial friction in all cases excepting the "Higley" sleeper "Chicago," and a few tests, as Nos. 60–64, where the start was made from a merely instantaneous stop.

Effect of Super-Elevation on a Tangent.—Fig. 5, illustrates another seeming discrepancy which may be noticed on every one of the record diagrams, viz., an abnormal depression in "resistance 4," which is for

the section of track immediately preceding the point of curve. The cause of this phenomenon cannot be given except that it is *not* due to any known or discoverable source of error. A single known source of minute error would, if corrected, increase the phenomenon. Under these circumstances the interesting speculation is raised whether it may not be due to the effect of the super-elevation, which is continued back over the whole 500 feet, the successive elevations being as follows: .06, .08, .12, .25, .22 (P. C). The amount of super-elevation seems hardly adequate for such an effect—which will average nearly or quite ½ lb. per ton, and is most clearly visible in the in the final and most accurate tests —but it is difficult to detect any other possible explanation.



Coefficient of Friction.—From all the preceding data, we may construct the following table (Table VI.) of coefficients of journal friction. Coefficients recently determined by Prof. R. H. Thurston, under similar conditions, are appended for the purposes of comparison.*

It will be observed in Table VI. that the coefficients of friction in motion are nearly twice as great as those determined by Professor Thurston's laboratory experiments, as was quite reasonable to expect. On the other hand, the coefficients of initial friction are somewhat lower, although in a large number of instances it was quite as high or higher. But it will be seen that the indications as to the laws of friction, viz., that it decreases materially as either the velocity or the load on the journal increases (within ordinary limits), and that the friction of rest is

* For the complete table published by Prof. Thurston, see R. R. Gazette, July 26, 1878.

several times greater than the friction of motion, are strikingly similar to Prof. Thurston's results. The general correctness of both is also strikingly confirmed by the brake experiments of Capt. Douglass Galton and Mr. Westinghouse, which have recently been described in "Engineering," and reprinted in the Railroad Gazette (July 26, 1878). One of the diagrams of these experiments is reproduced in Fig. 6, for convenience of reference. These concurrent indications are quite contrary to those which have been hitherto laid down, viz., that the effect of increasing load was, if anything, to increase the coefficient of friction instead of diminishing it.*

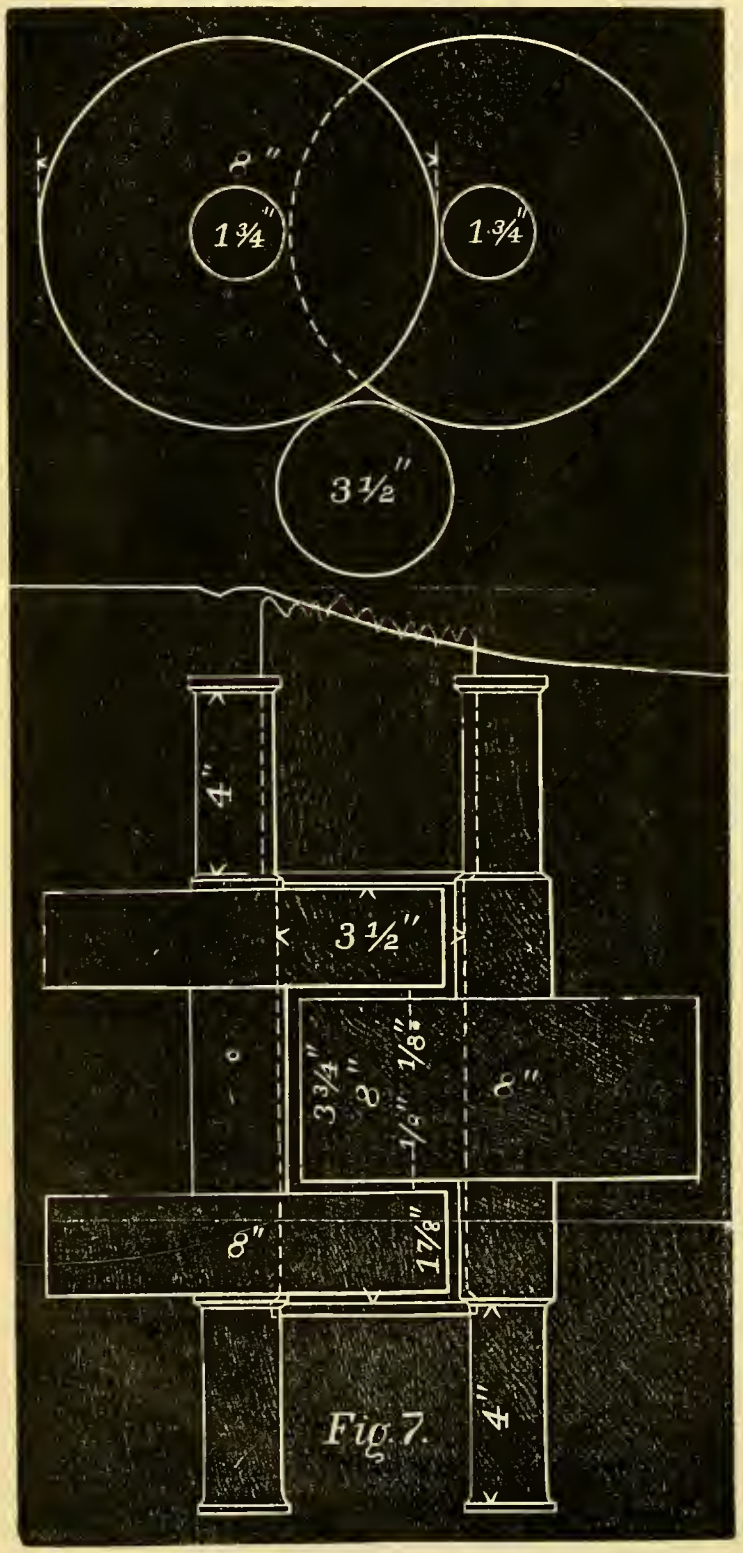


Fig. 7.

It is also apparent that the data in such standard textbooks as Weisbach (Vol. 1, pp. 319–322, Coxe's trans-

*e g., see "R. R. Gazette," August 16, 1878, pp. 400–1. for records of a number of old and recent European experiments.

lation) and Morin's data which have been copied into almost all text-books, need thorough revision and generally give quite excessive co-efficients.

Roller Journals.—Four tests have been made of anti-friction journals, viz., one horse-car, and one steam railroad car fitted with the Higley and the Wilcox patent bearings. The construction and dimensions of the Higley bearing are shown in Fig. 7, and it will be seen to be similar to the familiar grindstone bearings. The theoretical reduction of friction is 78 per cent., or 3.12 lbs. (assuming 4 lbs. per ton as the normal axle friction of plain bearings), leaving only .88 lbs. as the friction which should, in theory, remain.

Tests of the sleeping coach, "Chicago" fitted with this bearing, were repeated on three different days, in comparison with the sleepers "Adrian" and "Ohio." The net result was as follows :

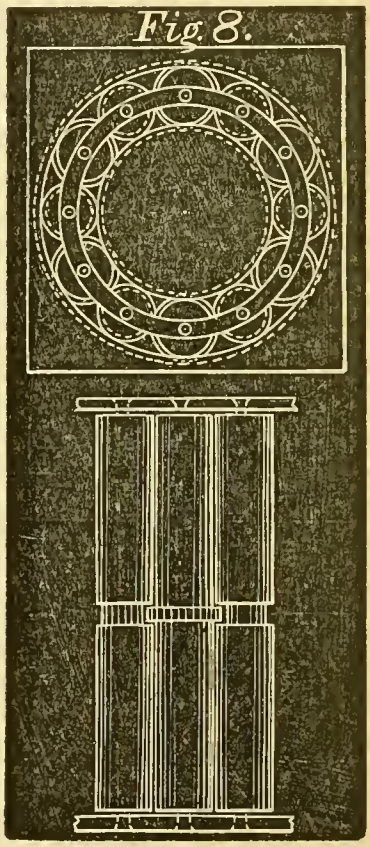
	Initial Friction.	Observed Axle Friction at velocities of 3 to 5 miles per hour.	Computed Axle Friction at high velocities. (All velocity resistance excluded.)
Sleeper Adrian	18 lbs. per ton ±	4.4 lbs. per ton.	3.5 lbs. per ton.
" Ohio	14 " " ±	4.4 " "	2.9 " "
Average	16 " " ±	4.4 " "	3.2 " "
Sleeper Chicago	4 " " ±	3.3 " "	2.8 " "
Saving	12 " " ±	1.1 " "	0.4 " "
Comparative resistance of Chicago (theoretical, 22 per cent.)	25 per cent.	75 per cent.	87½ per cent.
Truck alone of Sleeper Adrian	10 lbs. per ton ±	5.4 lbs. per ton.	5.0 lbs. per ton.
" " " Chicago	5 " " ±	5.0 " "	4.1 " "
Saving	5 " "	0.4 " "	0.9 " "
Comparative resistance of Chicago	50 per cent.	92 per cent.	82 per cent.

The Higley roller-journals have Babbitt-metal bearings, which have a lower coefficient of friction than brass. The load per square inch of journal is precisely the same.

These tests show that the Higley bearing is very nearly as effective as theory would indicate in reducing initial friction. The "Chicago" started off with perfect freedom on release of the brakes—whereas, the "Adrian" and "Ohio" had to be pinched or pushed to start in every

instance but one, and could be moved about the yard with conspicuous ease ;—but so rapidly does it lose this advantage when under speed, that it made but little better time even in the first 200 feet, and only a few seconds better in all the rest of the distance.

The Wilcox Journal, shown in Fig. 8, rests upon an entirely different principle. The interior of the journal-box is cylindrical, and the journal is surrounded by a series of rollers which nearly fill up the journal-box and revolve with the journal. The end-thrust is taken up by a groove, about three-eighths of an inch deep, cut in both journal and journal-box ; each alternate roller having a collar moving in these grooves.



The theoretical resistance of this bearing, on a tangent, is zero ; nor is it easy to see why some approach should not be made to this limit in practice. Only two or three of the rollers are in bearing at the same time, the rest being carried around loose by the collar which connects them. A minute difference of diameter in the rollers is practically unimportant, and the workmanship was very superior. Nevertheless, tests of a day coach, weighing 20.6 tons, and fitted with this journal, showed a saving of less than three-quarters of a pound per ton in axle friction, or only about 20 per cent. Like the "Higley," this car can be pushed about the yard with great facility.

This test was made on the Atlantic and Great Western Railroad. It is not deemed necessary to reproduce the notes.

Both the Wilcox and Higley bearings, however, make an excellent showing when applied to horse-cars. The comparative resistances are about as 5.3 lbs. to 10.25 lbs. with plain bearings ; the two bearings in these, as in the steam-car tests, showing substantially the same results. No explanation is attempted of this discrepancy.

42-Inch Wheels.

Comparative tests of cars fitted with 42-inch and 33-inch wheels show even more difference between their resistances than theory would indicate, as follows :

	Axle Friction at slow velocities.	Axle Friction at high velocities.
Coach 115, fitted with 33-inch wheels,	5.6 lbs. per ton.	5.2 lbs. per ton.
" 32, " 42 "	3.5 "	3.6 "
Difference.....	2.2 "	1.6 "
" per cent.	36 per cent.	31 per cent.

Theoretical saving $\left(\frac{42}{33}\right)$ 21.4 per cent.

This remarkably good showing may be in part deceptive, and due to an inadequate number of observations. The load per journal, also, was some six per cent. greater on the 42-inch wheels, which would operate in their favor. Both the coaches had been standing still for some time, and that or some other cause made the resistance of coach 115 unusually high.

Velocity Resistances.

Especial pains were taken to accumulate data for determining not only the aggregate amount, but the *constituent elements* of that portion of the rolling resistance which is due to velocity only, excluding the normal axle friction. The aggregate resistance from this cause must be made up, 1st, of air resistance against the end of the train; 2d, of air resistance along the side of the train; and 3d, of resistance due to oscillation and concussion. The general result of the investigation was to indicate that a suprisingly large proportion of the total velocity resistance arises from the latter cause.

The method used for determining the proportion of the aggregate resistance due to each one of the above causes was as follows :

Tests were made with both box and flat cars, both loaded and empty, and with from one to five cars of each, and the total resistance in pounds of each test, *due to velocity* (excluding axle and rolling friction), was determined (see Table II.) for one uniform velocity, which, for simplicity of computation, was taken at 10 miles per hour.

Then it is obvious that if, for example, we have a number of tests of loaded box cars, and a number of tests of empty box cars, all other conditions being similar the *atmospheric* resistance will be precisely the same for each. If, then, *all* the velocity resistance were caused by the air, it would be found that the total velocity resistance *in pounds per car* would be the same for both loaded and empty cars. On the other hand, the

oscillatory resistances will vary very nearly as the weight;* and if the observed total of velocity resistance should prove to be exactly as the weight, or nearly so, it will indicate that all or nearly all of such resistance is due to oscillation and concussion. The latter is found to be very nearly the case, as shown in the computation below.†

Similarly we may compare the resistances of flat and box cars. Having a considerable number of tests made under precisely the same conditions as to load, number of cars, &c., we may assume that all resistances will be the same for each, *excepting* the head resistances due to differences of cross-section. The oscillatory resistance might be slightly greater per ton for box cars than flat cars, but, on the other hand, the air resistance, *exclusive* of head resistance, would be greater per ton for flat cars, owing to their more irregular outline.‡

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* The centre of gravity of the *car body alone* is very nearly the same for the loaded and empty box cars, and is somewhat raised for loaded flat cars; so that there exists little, if any, reason why the oscillatory resistance should be less per ton for loaded than empty cars; and if it be assumed to be less, moreover, it would have the effect of increasing the already great proportion of oscillatory resistance deduced below. To *decrease* the relative importance of oscillatory resistance, we must assume that it is greater per ton for loaded than empty cars.

† Comparison of Velocity Resistances, Loaded and Empty Cars.—Six classes of experiments were made with each, viz., flat and box cars, loaded and empty: one, two and five cars each, of the empty cars; and two, three and five cars each, of the loaded cars (the "three car" tests of loaded cars, so-called, were in reality two loaded and one empty car to a train, but it classed in, for convenience as a loaded train). The average of all the loaded and all the empty experiments is taken, in default of a sufficient number of experiments to eliminate the errors in comparisons of single tests, as follows:

Average weight of a flat and box car $\frac{8.9+7.5}{2}=8.2$ tons.

Average number of cars per train, empty cars, $\frac{1+2+5}{3}=2\frac{2}{3}\times 8.2$ tons $=21.9$ tons average weight of train.

Average number of cars per train, loaded cars, $\frac{2+3+5}{3}=3\frac{1}{3}\times 8.2$ tons $=27.3$ tons.

Average load of loaded train $\frac{2+2+5}{3}=3$ car loads $\times 12$ tons $=36.0$ tons.

Total weight of loaded trains 63.3 tons.

Resistance per ton at 10 miles per hour (see Table 4). Empty cars 1.62 lbs.; loaded 0.848 lbs.

Then 21.9 tons of empty cars $\times$ 1.64 lbs. per ton $=$ 35.4 lbs. total resistance.

And 63.3 tons of loaded cars $\times$ 0.848 lbs. per ton $=$ 53.7 lbs. total resistance.

Differences 41.4 tons of weight, and 18.3 lbs. total resistance.

Hence the resistance, which varies directly as the weight, is

$\frac{18.3}{41.4}=.444$ lbs. per ton. Then $\left\{\begin{array}{l}21.9 \text{ tons, weight of empty trains}\\ 63.3 \text{ " " loaded "}\end{array}\right\}\times .444=$

$\left\{\begin{array}{l}9.7 \text{ lbs. for empty car trains}\\ 21.5 \text{ " loaded "}\end{array}\right\}$ as the total resistance, which varies with the weight, leaving

$\left\{\begin{array}{l}35.4-9.7=25.7 \text{ lbs. in the case of empty trains}\\ 53.7-21.5=32.2 \text{ " " " loaded "}\end{array}\right\}$ which, divided by the number of cars per train, leaves 9.7 lbs. per car as the resistance, which is independent of weight, and, hence, must be caused (presumably) by bulk and air resistance.

‡ Comparison of Velocity Resistances, Flat and Box Cars.—In the total of six classes of experiments with flat and box cars separately, viz., one, two and five empties, two and five

Finally, we have still another method of eliminating the head resistance from the other velocity resistances, viz., by comparing tests made under similar conditions, except as to number of cars in the train. All other resistances than the head resistance, in this case, will presumably vary very nearly with the number of cars in the train, and from a comparison of this kind, as shown in the foot-note below, we deduce that the head resistance amounts to .208 lbs. per square foot at ten miles per hour, and the remaining resistances to .82 lbs. per ton.*

Summarizing the results of these various computations, we have—

Velocity resistance at 10 miles per hour.	Head resistance.	Air resistance per car.	Oscillating resistance.
From comparison by number of cars... (Av. wt. per car 14.2 tons.)	.19 lbs. per sq. ft.	.82 lbs. per ton.	
From comparison of loaded and empty tests..... (Av. area of cross section 63.55 sq. ft.)	9.7 lbs. per car.		.444 lbs per ton.
From comparison of flat and box-car tests..... (Av. wt. per car 14,2 tons.)	.3 lbs. per sq. ft.	.8 lbs. per ton.	

loaded, and two loaded and one empty, there were nine loaded and nine empty cars dropped; an average of one and one-half loaded, and one and one-half empty cars to each test.

End section of flat car 24.9 sq. ft. + 20 ft. for truck = 44.9 sq. ft.
" " box car 62.2 " + 20 " " = 82.2 "

Difference.....37.3 "

Average velocity resistance at ten miles per hour (see Table 4):

Average of all flat car tests 1.19 lbs. per ton.
" " box car " 1.38 " "

3 flat cars × 7.5 tons each = 22.5 tons + 18 tons av. load = 40.5 tons × 1.19 lbs. = 48.2 lbs.
3 box cars × 8.9 tons each = 26.7 tons + 18 tons av. load = 44.7 tons × 1.38 lbs, = 61.7 lbs.
Differences 4.2 tons, 13.5 lbs. of velocity resistance.

Of this difference of 13.5 lbs. we may estimate that 2.1 lbs. ($\frac{1}{2}$ lb. per ton) is due to the difference in oscillating resistance of the two trains, leaving 11.4 lbs. as the difference due to difference of cross-section. Then $\frac{11.4 \text{ lbs}}{37.3 \text{ sq. ft.}} = .304$ lbs. per sq. ft. for head resistance at ten miles per hour, and this resistance deducted from the total leaves about .8 lbs. per ton due to the other velocity resistances.

* Comparison of Velocity Resistances, Two Car and Five Car Trains.—Four classes of each were tried, viz., loaded and empty, flat and box cars. Average weight of cars, 8.2 tons + $\frac{12.0}{2}$ = 14 2 tons = 28.4 tons for two car trains, and 71 0 tons for five car trains. The average end areas were the same, and the average bulk proportional to the number of cars

Average velocity resistance at ten miles per hour (see Table 4):

2 car trains 1.284 lbs. per ton.
5 " 1.05 " "

Then 28.4 tons × 1 284 = 36.47 lbs.
And 71.0 " × 1.05 = 71.35 "

Differences 42.6 " of weight, and 34 88 " resistance = .82 lbs. per ton.

This .82 lbs. per ton, ∕ weight of each train and subtracted from the total velocity resistance above leaves 13.2 lbs. head resistance. The average end area of flat and box cars $\frac{44.9 \times 82.2}{2}$ = 63.55 square feet, and $\frac{13.2 \text{ lbs.}}{63.55 \text{ sq. ft.}}$ = .208 lbs. per square foot head resistance at 10 miles per hour.

Distributing proportionately the undistributed elements above (by the aid of the data given in brackets) as nearly as may be judged, we have—

Velocity resistance at 10 miles per hour.	Head resistance.	Air resistance per car.	Oscillating resistance.
From comparison by No. of cars	.21 lbs. per sq. ft.	4.54 lbs. per car.	.5 lbs. per ton.
" of loaded and empties.....	.10 " "	2.80 " "	.44 " "
From comparison of box and flat cars.....	.30 " "	4.26 " "	.5 " "
Assumed average.....	.20 lbs. per sq. ft.	4.2 lbs. per car.	.5 lbs. per ton.

The correctness of these assumed or preliminary formulæ was then tested by comparing the *actual* velocity resistance of each test with that given by the sum of these separate formulæ. These comparisons, details of which are given in Table VII. herewith (as explained in foot-note to Table VII.), indicated that the preliminary formulæ should be corrected as follows:

Head resistance, .17 lbs. per square foot, at 10 miles per hour.

Air resistance per car { box, 3.0 lbs. per car, at 10 miles per hour.
flat, 5.0 " " " "

Oscillating resistance .5 lbs. per ton " "

Axle and rolling friction, loaded freight cars and passenger cars, 3.9 lbs. per ton.

Axle and rolling friction, empty freight cars, 6.0 lbs. per ton.

The process above detailed is not as exact and scientific as it might have been made with a greater body of data, but those which we have, it is believed, are trustworthy within a small margin of error, and, if so, furnish ample evidence that the above distribution of the velocity resistance must be substantially accurate, as will be found by testing the effect on the data given in Table VII. of any essential variation in them. The discrepancy will be so great as to be quite inadmissible without wholly discrediting the data before us.

It appears probable, therefore, that the head resistance of a single loaded box-car, having 82.2 square feet sectional area, amounts to no more than 82.2×.17=14 lbs. resistance at 10 miles per hour. For a train of twenty such cars we have:

Head resistance.....14 lbs.
Side and top resistance 3.0 lbs. per car×20=....60 "

Total atmospheric resistance.....74 lbs.
Oscillatory resistance, 20×20×.5 lbs.=.....200 lbs.

TABLE VII.

Showing the Observed Total of Velocity-Resistance in each Experiment in Comparison with the Total deduced from Formulæ for its Constituent Elements. (All Axle and other Friction independent of Velocity e cluded.)

Class of Experiment.	Actual Velocity-Resistance at 10 Miles per Hour, as given in Table IV.			Computed Velocity-Resistances at 10 Miles per Hour											
				By Preliminary Formulæ.						By Corrected Formulæ.					
				Atmospheric.		Oscillatory, .5 lb. per ton.	Total Veloc.-Resist. in lbs.	Errors in Do.		Atmospheric.		Oscillatory, 5 lbs. per ton.	Total Veloc.-Resist. in lbs.	Errors in Do.	
	Lbs. per ton.	Wt. in Tons.	Total Resist. in lbs. excl'g. axle friction.	End Resist., 2 lb. per sq. ft.	Per car 4.2 lbs.			+	—	End Resist., 17 lbs. per sq. ft.	Per car 5.3 lbs.			+	—
1 empty flat car.....	1.830	7.50	13.7	5.32	4.2	3.75	13.27	....	0 4	4.5	5.0	3.75	13.3	.....	0.4
1 " box "	2.400	8 90	21.3	16.44	4 2	4.45	25.09	3.8	.....	14.0	3.0	4.45	21.4	0.1	.....
2 " flat "	1.430	15 00	21.5	5.32	8.4	7.50	21.22	....	0.3	4.5	10.0	7.50	22.0	0.5	.....
2 " box "	1.470	17.80	26.2	16.44	8.4	8.90	33.74	7.5	.....	14.0	6.0	8.90	28.9	2.7	.....
5 " flat "	1.300	37.50	48.9	5.32	21.0	18.75	45.07	....	3.8	4.5	25.0	18.75	48.3	.....	0.6
5 " box "	1.400	44 50	62.3	16.44	21.0	22.25	59.69	....	2.6	14.0	18.0	22.25	44.2	.....	18.1
2 loaded flat "	0.926	39.00	36.0	5.32	8.4	19.50	33.22	....	2.8	4.5	10.0	19.50	34.0	.....	2.0
2 loaded box "	0.840	41.80	35.0	16.44	8.4	20.90	45.74	10.7	.....	14.0	6.0	20.90	40.9	5.9	.....
2 loaded and 1 empty flat cars.....	0.890	46.50	41.4	5.32	12.6	23.25	41.15	. .	1.2	4.5	15.0	23.25	42.8	1.4	.....
2 loaded and empty flat cars.....	0.940	50 70	47.6	16.44	12.6	25.35	54.39	6.8	.....	14.0	9.0	25.35	48.3	0.7	.....
5 loaded flat cars.....	0.775	97.50	75.5	5.32	21.0	48.75	75.07	....	0.4	4.5	25.0	48.75	78 2	2.8	.....
5 loaded box cars.....	0.714	104.50	74.7	16.44	21.0	52.25	89.69	15.0	.....	14.0	18.0	52.25	84.2	9.5	.....

Sleeper Chicago, 2d test..	1.300	34 50	44.9	21.2	5.0	17.25	43.95	....	0.9	18.0	5.0	17.25	40.3	.....	3.6
" 3d test..	1.300	34.50	44.9	21.2	5.5	17.25	43.95	....	0.9	18.0	5.0	17.25	40.3	.....	3.6
Sleeper Adrian.....	1.490	34.00	50.6	21.2	5.5	17.00	43.70	....	16.9	18.0	5.0	17.00	40.0	.....	10.6
Sleeper Ohio.....	1.140	34.00	38.8	21.2	5.5	17.00	43.70	4.9	....	18.0	5.0	17.00	40.0	1.2	....
Coach 39, 6 wheel truck...	1.810	21.00	37.9	20 0	5.0	10.50	35.50	....	2.4	17.0	4.5	10.50	32.0	.....	5.9
Coach 41, 4 " ...	1.810	20.00	36.1	20.0	5.0	10.00	35.50	....	0.6	17.0	4.5	10.00	31.5	.....	4.6
Coach 39, 41, Adrian, Chicago....	0.748	109.50	82.1	21.2	21.0	54.50	96.70	14.6	.....	18.0	19.0	54.50	91.5	9.4	.....
Passenger coach, 33 in. wheel.....	1.130	20.00	22.6	20.0	5.0	10.00	35.00	13.6	.....	18 0	4.5	10.00	32 5	9.9	.....
Passenger coach, 42 in. wheel.....	1.120	22.00	24.6	20.0	5.0	11.00	36.00	9.4	....	18.0	4.5	11.00	33.5	8.9	.....
2 Passenger coach, 33 in. and 42 in. wheel.....	0.892	42.00	37.5	20.0	10.0	21.00	51.00	13.5	.....	18.0	9.0	21.00	48.0	10.5	.....

Total error on box car ..... +41.2
" flat cars..... —7.9
" empty cars..... +4.1
" loaded cars..... +28.1

Total error on box cars..... +0.8
" flat cars ..... +1.7
" empty cars..... —16.7
" loaded cars..... +18.3
" 1 and 2 car trains —4.3
" 3 and 5 car trains +6.8
Total error on all car trains, +2.5 lbs. in 504.1 lbs.

REMARK.—The experiments on passenger rolling stock were not used in determining the distribution of the velocity-resistance, the number of experiments being too few and irregular. It will be seen, however, that the distribution harmonizes reasonably well with the exception of the last three tests which, for some unknown reason, have an unusually low resistance, possibly because the close of the test where the tract was more exposed to wind, might have been affected by a favoring breeze imperceptible at the starting point. The regularity of the record-diagrams will show that the computations must be substantially correct. It will be noticed that the passenger tests indicate, if anything, a lower atmospherie resistance than the freight car tests.

Or, in other words, nearly three-quarters of the total resistance from velocity appears to arise from oscillation and concussion, and only one-quarter from atmospheric resistance.

To this very surprising—and quite unexpected—result, the objection will, doubtless, be raised, that accepted authorities give an estimate of air resistance per square foot from three to six times greater than the above. Thus, Smeaton's table, quoted in most of our text-books, gives .5 lbs. per ton as the air-resistance at 10 miles per hour, and D. K. Clark's recently published "Manual for Mechanical Engineers" rejects even this as too small, and gives data* tending to show that the resistance is 1 lb. per square foot at 10 miles per hour, *and increases rapidly with the area.* The simple calculation in the foot-note below, however, proves beyond question that these current formulæ, when applied to areas of the size of a box-car and to ordinary train-speeds, are in excess by from 250 to 500 per cent.; for it appears that if Smeaton's formula were correct, the maximum velocity attained by an empty box-car descending a grade of 37 feet per mile would be only 13.24 miles per hour without allowing anything whatever for oscillatory resistance; while the velocity actually observed for such a car was 17.5 miles per hour, *which was still increasing* after descending 6,200 feet. If D. K. Clark's data were correct, the maximum velocity attained would be only 9.36 miles per hour. If the air resistance be taken at .17 lbs. per ton, as above, the maximum velocity attainable, if there were no oscillatory resistance whatever, would be 22.68 miles per hour.†

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* On p. 897. Data "reduced from Jas. C. Fairweather's Exp'ts. Proc. Royal Soc. Edinb. 1872-5."

† Weight of box-car, 9 tons. Rolling and axle friction, 6 lbs. per ton. Grade .7 per 100= 14 lbs. per ton accelerating force.

Then, if the air resistance be ½ lb. per square foot at 10 miles per hour, we have 82.2 sq. ft. ×,5=41.1 lbs., =0.411 lbs. at 1 mile per hour; and we have, letting V= the maximum velocity attained in descending the given grade,

$$0.411\ V^2 + (6 \cdot 9) = (14 - 9)$$

as the equation of maximum velocity attainable.

$$\text{whence} \qquad V^2 = \frac{72}{0.411}$$

$$\text{and} \qquad V = 13.24 \text{ miles per hour.}$$

If the air resistance be 1 lb. per square foot, as by D. K. Clark's data, we have

$$0.822\ V^2 + 54 = 126$$

$$\text{whence} \qquad V^2 = \frac{72}{0.882}$$

$$\text{and} \qquad V = 9.36 \text{ miles per hour.}$$

If the air resistance be only .17 lbs. per square foot, we have

$$V^2 = \frac{72}{.14}$$

$$V = 22.68 \text{ miles per hour.}$$

It may be proved in another way that the atmospheric resistance cannot be much greater than that deduced above. A "brisk gale," by Smeaton's classification, is 25 miles an hour, and a freight train moving against it plainly encounters an AIR resistance due to a speed of about 40 miles per hour. Yet freight trains usually pull through such gales without much detention, although it will be plain from the diagram submitted herewith (Plate X,) that even the seemingly low air resistance there shown increased the train resistance in such a case about fifty per cent. If the air resistance be in fact two or three times greater than deduced above, a head-wind of 25 miles an hour would absolutely prohibit motion, even on a level.

The conclusion, therefore, is irresistible, that the main portion of the velocity resistance arises from oscillation and concussion; and this fact indicates a great field for future improvement.

From the formulae just given, we may construct an equation which shall be correct within (it is hoped) a small margin of error, for any one train, but it is plain that no general formula can be devised which shall be even approximately correct for all classes of trains. If we estimate those locomotive resistances which are a tax upon the adhesion (thus excluding all internal friction and the axle friction of the drivers) as approximately the same per ton as for the train, viz.: 4 lbs. per ton (and probably no simple assumption would be so nearly correct), we shall obtain for an average train of 20 loaded box cars the following equation of resistance :

Weight of cars $9 + 11 = 20$ tons each $\times$ $20 = 400$ tons $+ 60$ tons for engine and tender = ...	460 tons.
Rolling friction proper	3.9 lbs. per ton.
Velocity resistances at 10 miles per hour	
Head resistance (estimating it as double that observed for cars, on account of the irregular outline of the locomotive) 28 lbs. $\div$ 460 = ...	.061 lbs. per ton.
Air resistance per car (taking engine and tender = 2 cars) 3 lbs. $\times$ 22 = 66 lbs. $\div$ 460 = ...	.143 " "
Oscillation and concussion ($\frac{1}{2}$ lb. per ton for 400 tons of cars, and 1 lb. per ton for 60 tons of engine) = 260 lbs $\div$ 460 = ...	.562 " "
Total velocity resistances at 10 miles per hour ..	.766 " "

Equation of total resistance $R = 3.9 + .00766\ V^2 = 3.9 + \frac{V^2}{130.5}$

From this equation the curve of resistance for loaded trains on Plate X, was constructed.

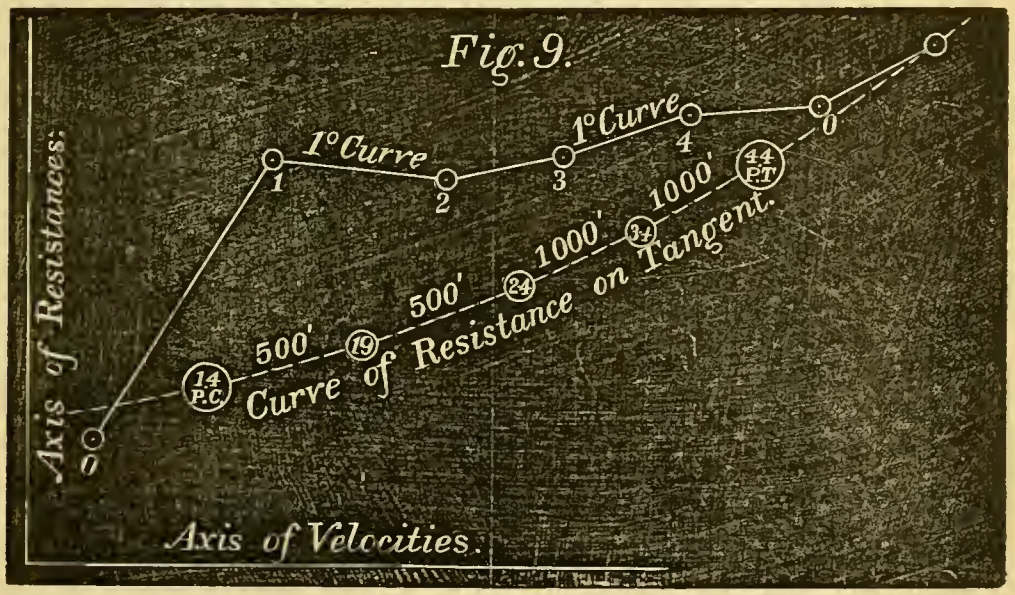
In the same way we may compute the equation of total resistance for various other trains as follows :

20 loaded box cars....	$\frac{V^2}{130}$		20 loaded flat cars....	$\frac{V_2}{113}$	
30 " "	$\frac{V^2}{136}$	+3.9	30 " "	$\frac{V^2}{117}$	+3.9
40 " "	$\frac{V^2}{140}$		40 " "	$\frac{V^2}{120}$	
30 empty "	$\frac{V^2}{100}$		30 empty "	$\frac{V^2}{78}$	
40 " "	$\frac{V^2}{106}$*	+6.0	40 " "	$\frac{V^2}{81}$	+6.0
50 " "	$\frac{V^2}{109}$		50 " "	$\frac{V^2}{82}$	

To the diagram given in Plate X, D. K. Clark's formula for train resistance, which is, perhaps, the most authoritative and generally known, is given for purposes of comparison, viz.:

$$R = \frac{V^2}{171} + 8 \text{ for tons of 2 240 lbs.} = \left\{ R = \frac{V^2}{181.5} + 7.14 \right\}$$

for tons of 2 000 lbs. It will be observed on Plate X, that this formula gives a noticeably higher resistance than those deduced above for low



1, 2, 3, 4, Curve resistances. 0, 0, Tangent resistances. A known cause exists (as explained) why the resistances 0, 0, should be computed slightly greater than the truth. No known cause exists for variation in the computed resistances 1, 2, 3, 4, except an actual difference in the curve resistance.

* From this equation the line of total resistance per ton for empty cars, shown on Plate X, was plotted.

velocities, and lower resistance by a nearly equal amount for very high velocities. As the writer has as yet made no experiments at higher velocities than about 30 miles an hour, he would not assert that Mr. Clark's formula may not, possibly, be nearer correct as respects the increase of resistance from velocity, but this, at least it is believed, may safely be asserted, that Mr. Clark's CONSTANT is certainly erroneous, and nearly twice too great, and it therefore appears possible that his whole formula may have been modified by an erroneous determination of the low velocity resistances; and possibly the peculiar aberrations of the initial friction which are also shown in Plate X, may have had something to do with the latter.

Curve Resistance.

Fig. 9 shows the general outline of the record diagrams on that portion of the test track covered by the curve. Reading off the curve resistance was, therefore, a mere matter of observation, and the result of these readings for the various tests is shown in Table 8, from which it appears that the average curve resistance was .83 lbs. per ton for 4-wheel trucks (5 feet wheel base), and .93 lbs. per ton for 6-wheel trucks ($10\frac{2}{3}$ feet wheel base), the latter, however, not being deduced from a sufficient number of observations to give more than an indication in respect to the difference in resistance due to length of wheel base. In Table 9 are given the notes of some experiments at Altoona, Pa., on an 8° curve, from which it appears that the resistance was about 8.6 lbs. per ton at a speed of about 8 miles per hour, and about 6.6 lbs. per ton at a speed of 19 miles per hour. The experiments on the 1° curve show an average resistance of 1.2 lbs. per ton on the first 500 feet of the curve, at an average speed of about 13 miles per hour, and of only 0.5 lbs. per ton at the lower end of the curve at an average speed of about 21 miles an hour.

These results, and the general outline of the line of curve resistance shown in Fig. 9, clearly indicate that the resistance of curvature decreases noticeably with the speed, and apparently indicate also that there is considerable extra resistance in entering upon any curve at any speed. It should also be noted that this latter cannot be due to a mere shock, but must be some cause extending over a considerable period of time to cause an appreciable difference in the resistance deduced for a run of 500 feet.

TABLE VIII.

Curve Resistance on a 1° Curve, as read off from the Record Diagrams.

	Curve Resistance in Lbs. per Ton.		
	At beginning of curve average velocity 12 miles per hour.	At end of curve average velocity 22 miles per hour.	Average velocity 17 miles per hour.
1 Empty flat-car	1.5	0.9	1 2
1 " box "	.8	0.2	0.5
2 " flat "	1.6	0.7	1.15
2 " box "	1.1	0.5	0.8
5 " flat "	1.1	0.4	0.75
5 " box "	1.2	0.8	1.0
Average of empty cars	1.2	0.6	0.9
2 Loaded flat-cars	2.1	0.5	1 3
2 " box "	0.8	0.3	0.55
2 " and 1 empty flat-cars	1.6	0.8	1.2
2 " " " box "	0.7	0 4	0.55
5 " flat-cars	0 6	0.6	0.6
5 " box "	1.4	0.4	0.9
Average of loaded cars	1.2	0.5	0.85
1 Pass'r. coach, 4 wheel truck, 33 in. wheels	1. 2	0.4	0.8
1 Pass'r coach, 4 wheel 42 in. wheels	0. 9	0.7	0.8
2 Pass'r coach together, 33 in. and 42 in. wheels	1. 0	0.7	0.85
1 Pass'r coach, 4 wheel, 33 in. wheels	1. 4	0.7	1.05
1 Pass'r coach, 2d trial	0. 9	0.7	0.8
Av'ge of 8 wheel pass'r coaches.	1.1	0.6	0.85
1 Pass'r coach, 6 wheel trucks.	1.2	0.4	0.8
1 Sleeping " Adrian	1.3	0.8	1.05
1 " " Ohio	1.1	0.7	0.9
1 " " Chicago	0.4 0.6 0.8	0.4 0.3 0.4	0.5
4 Coaches together, 3 sleepers and 1 day coach, 8 wheel	1.4	0 7	1.05
Av'ge of 12 wheel pass'r coaches.	1.1	0.6	0.85

Remark. No attempt at great accuracy was made in reading off the above curve-resistances (which may be checked off by inspection of the record diagrams), but the initial resistance was, if anything, read off too small in each case. The average of the class of 12 wheel passenger coaches would be 0.1 to 0.2 lbs. per ton higher except for the very low curve resistance of the sleeper "Chicago" (fitted with Higley roller-journals), which may possibly have been somewhat affected thereby.

TABLE IX.

EXPERIMENTS ON CURVE RESISTANCE AT ALTOONA, PA., NOV. 10, 1877.

Stations.	Alignment.	Time in sec'ds.	Av. Vel. ft. per sec.	In. and Terminal vels. at each Station.	Avs. of do. or Vels. at each Sta. ft. per sec.	Corresp. fall = vel. head in feet.	Diffs. of do. feet.	Actual fall feet.	Fric. fall = diffs. of actual fall and vel. head.	Corresp. grade of repose and resist. in lbs. per ton.	Est'd tang. resistance $R = .0075\,V^2 + 6$.	Curve Resistance proper 8° curve.
	8° curve L.											
3+50		48.9 in.	7.18	14.36 15.20	14.78	3.40	3.40	5.95	2.55	0.73 = 14.6 lbs.	6.20 lbs.	8.4 lbs
6+50	P. T.	16.8 in.	17.85	20.5 19.0	19.75	6.07	2.67	5.10	2 45	0.825 = 16.5 "	7.19 "	9.4 "
10+50	P. C. 8° R.	18.5 in.	21.62	24.3 24.4	24.35	9.20	3.13	6.80	3.67	0.912 = 18.24 "	7.75 "	10.5 "
17+50	P. T.	24.9 in.	28.11	31.9 31.3	31.60	15.50	6.30	11.90	5.60	0.800 = 16.00 "	8.75 "	7.25 "

REMARK.—These notes are the average of ten successive tests of a train of 3 days coaches, weighing 19 tons each, and one Pullman parlor car weighing 28 tons, a total of 85 tons. They were timed with an ordinary watch only, and levels were not taken on the track, which may have varied considerably from the average (1.8 feet per 100, or 89.76 feet per mile). The equation of tangent resistance is the same as shown in Table IV for a similar train tested on the L. S. & M. S. Ry., as respects the velocity-resistance, the constant is taken higher, 6 lbs. per ton, which may be considered a maximum, as the same train showed a tangent resistance of only 4.7 lbs. in a subsequent test. The above test was continued some distance further out on a different grade, of which the writer has no notes.

Summary.

We may summarize the various conclusions reached in the preceding paper, as follows :

1st. The axle and rolling friction of empty freight cars may be taken as 6 lbs. per ton of 2 000 lbs. The axle and rolling friction of coaches and loaded freight cars may be taken as 4 lbs. per ton. The fluctuations from these limits are small, rarely exceeding 1 lb. per ton in single cars, or $\frac{1}{4}$ to $\frac{1}{2}$ lb. per ton in a train.

2d. The initial resistance at the instant of starting is several times greater than this, and greater for loaded than for empty cars, being at least 18 lbs. per ton for loaded cars, and 14 lbs. per ton for empty cars, as an average, but fluctuating considerably. Its amount probably varies with the length of stop, according to unknown laws.

3d. Most of this initial resistance is almost wholly instantaneous and consumes little power. Enough of it still remains, however, to increase the normal axle friction in the first few car lengths by at least 2 lbs. per ton.*

4th. The air resistance against such a surface as the end of a box-car (about 80 square feet) is less than $\frac{1}{5}$ lb. per square foot at a velocity of 10 miles per hour, and (presumably) increases as the square of the velocity. The current estimates of this resistance ($\frac{1}{2}$ lb. to 1 lb. per square foot) are erroneous by from 250 to 500 per cent., when applied to surfaces of that size.

5th. About two-thirds of the velocity resistance proper, excluding the normal axle friction, is due to oscillation and concussion. The resistance due to this latter cause alone may be estimated at $\frac{1}{2}$ lb. per ton at a velocity of 10 miles per hour, varying as the square of the velocity.

6th. The resistance of curves decreases materially with the velocity and appears to be greater by a considerable percentage in the first 200 to 500 feet than on the rest of the curve.

7th. The resistance of a 1° curve is over 1 lb. per ton at a velocity of 12 miles per hour, and decreases to about $\frac{1}{2}$ lb. per ton at a velocity of 22 miles per hour. The resistance of an 8° curve is over 8 lbs. per ton at a velocity of 9 miles per hour, and decreases to about $6\frac{1}{2}$ lbs. per ton (probably) at a speed of 19 miles per hour.

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* This, of course, does not include, nor in any way refer to, the additional power demanded to get up speed, which is 2 lbs. per ton to give a speed of 10 miles per hour in 3 340 feet, or 4.5 lbs. per ton to give a speed of 15 miles per hour in the same distance.

8th. The average resistance of a 1° curve to 4-wheel trucks, having a 5-foot rigid wheel-base, and to 6-wheel trucks having a $10\frac{2}{3}$ foot rigid wheel-base (except for the play of the boxes in the pedestal-jaws), appear.

9th. It appears possible that the act of coupling together cars by a loose link slightly decreases the axle friction; and hence, presumably, the oscillating friction at high velocities. The average reduction observed from coupling four or five cars together appeared to be as much as $\frac{1}{2}$ pound per ton.

10th. There appear to be good grounds for suspecting that a slight super-elevation of one rail on a tangent may have the effect of appreciably reducing the resistance to motion even at velocities of ten or twelve miles per hour.

11th. Roller journals of various forms appear to be very effectual at velocities of 0 +, but lose nearly all their theoretical advantage as the velocity increases. Such journals appear to be more effective as the load is decreased, and reduce the resistances of empty horse-cars by about one-half.

12th. Forty-two inch wheels seem to be even more effectual than theory would indicate in reducing extra friction.

13th. The equation of resistance for average trains (twenty cars) of loaded box cars may be taken, approximately, as

$$R = \frac{V^2}{130} + 4$$

or, for trains of forty empty box cars,

$$R = \frac{V^2}{106} + 6$$

The velocity-resistances of flat cars increase somewhat more rapidly, being for twenty loaded flat-cars $\frac{V^2}{113}$ and for forty empty flat-cars $\frac{V^2}{81}$

These formulæ are believed to be closely approximate up to velocities of thirty miles per hour. No tests were made at higher velocities.

14th. The co-efficient of axle friction is about .02 for loaded freight cars and passenger coaches at speeds of over five miles per hour, about .03 for empty freight cars, about .065 for horse cars, and about .12 for freight trucks without load. The co-efficient is two to three times greater at the instant of starting. It decreases rapidly as the load per journal increases.

Table II.

Showing the values of the Constants in the Equation of Resistance as deduced from each of the tests shown on the Record Diagrams. (Equation $R = f V^2 + C$, in which $C =$ the constant friction independent of velocity, and $f =$ the velocity-resistance at one mile per hour.

Description of Test.	No. of single tests av'ged.	Observed Axle and Rolling Fric. at vel. of 0+. lbs. per ton.	Computed Values of c and f. Vals. of c, = axle fric. at vel. of 0 +. lbs. per ton.	Val. of f = coeff. of velocity resist. lbs. per ton.
1 empty flat-car	1	6.0	5.7	.0183
1 " box-car	1	7.5	6.6	.024
2 " flat-cars	3	6.0	6.1	.0143
2 " box-cars	4	6.5	6.8	.0147
5 " flat-cars	4	5.8	5.2	.013
5 " box-cars	4	6.0	5.6	.014
2 loaded flat-cars	3	4.5	4.4	.00926
2 " box-cars	3	4.0	3.8	.0084
2 " and 1 empty flat-car	1	4.7	4.4	.0089
2 " " " box-car	1	3.7	3.35	.0094
5 " flat-cars	2	4.0	3.5	.00775
5 " box-cars	2	4.5	4.1	.00714
1 freight truck	1	5.0	5.7	028
1 passenger truck	2	5.4	5.0	.0183
1 " (Highley box)	2	5.0	4.1	.0151
1 horse car, plain box	1	10.0	10.4	.050
1 " second test	1	10.0	10.7	.046
1 " Wilcox box	2	5.2	5.2	.047
1 " Higley box	2	5.4	5.4	.051
1 passenger coach, 33-in. wheels	2	5.6	5.2	.0113
1 " " 42-in. "	2	3.5	3.6	.0112
2 " " 33-in. & 42-in. together	1	4.0	3.6	.0089
1 " " 4 wheel truck	3	4.2	4.2	.018
1 " " 6 wheel "	3	4.0	3.8	.0197
1 " " sleeper, "Adrian"	3	4.4	3.5	.0130
1 pass'r coach, sleeper "Chicago," 2d test	6	4.5	3.4	.0130
4 " coaches, together	1	3.8	3.5	.00748
1 " coach, sleeper "Ohio"	6	4.4	2.9	.0114
1 " " " "Chicago," 3d test	6	3.0	2.8	.013
Averages of the Above.				
Average of all flat-car tests		5.12	4.89	.0119
" " box-car "		5.37	5.04	.0130
" " loaded freight car tests		4.23	3.92	.00848
" " empty " "		6.30	6.00	.0164
" " two-car tests		5.33	5.20	.01284
" " five-car "		5.07	4.60	.0105

Remarks.—The journals of the above cars averaged $3\frac{1}{4}$ in. x 6 in., varying in diameter from 3 in. to $3\frac{1}{2}$ in., and in length from $5\frac{5}{8}$ to $6\frac{2}{3}$. Almost all of them, however, were $3\frac{1}{4}$ x 6. The "number of single tests averaged" might fairly be stated about three times as great, inasmuch as each test was computed in two different ways and the time record of each was also taken at least twice independently. A considerable number of tests have been excluded for various imperfections.

Table IV.

Computation of the Initial Resistances of Tests 3–11.—Two loaded Box-cars. (Showing the causes of apparent anomalies in the Record Diagrams as outlined in Fig. 6.)

Computation 1.

Computation as recorded on Diagram ; no allowances made for sources of error.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Station.	Average Time between Stations.	Average Velocity in feet per second.	Computed Initial and Terminal Velocity at each Station.	Averages of Initial and Terminal, or Velocity at each Station.	Velocity-Head in feet.	Differences of Velocity-Head in feet.	Actual Fall between Stations.	Friction-Head = Differences of Cols. 8 and 9.	Corresponding rate of Grade per 100 feet.	Corresponding Resistance in lbs. per ton = Cols 10 × 20.
	Secs.									lbs.
0.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2.....	60.4	3.32	Ter. 6.64 In. 8.05	7.34	0.84	0.84	1.38	0.54	0.27	5.4
4.....	20.5	9.76	Ter. 11.44 In. 11.24	11.34	2.00	1.16	1.38	0.22	0.11	2.2
9.....	35.3	14.16	Ter. 17.05 In. 16.80	16.92	4.44	2.44	3.57	1.13	0.236	4.52
14 P. C.	26.45	18.90	Ter. 21.00 In. 20.20	20.6	6.60	2.16	3.38	1.22	0.244	4.88
19.....	22.98	21.93	Ter. 23.60 In. 23.50	23.55	8.65	2.05	3.63	1.58	0.316	6.32

Computation 2.

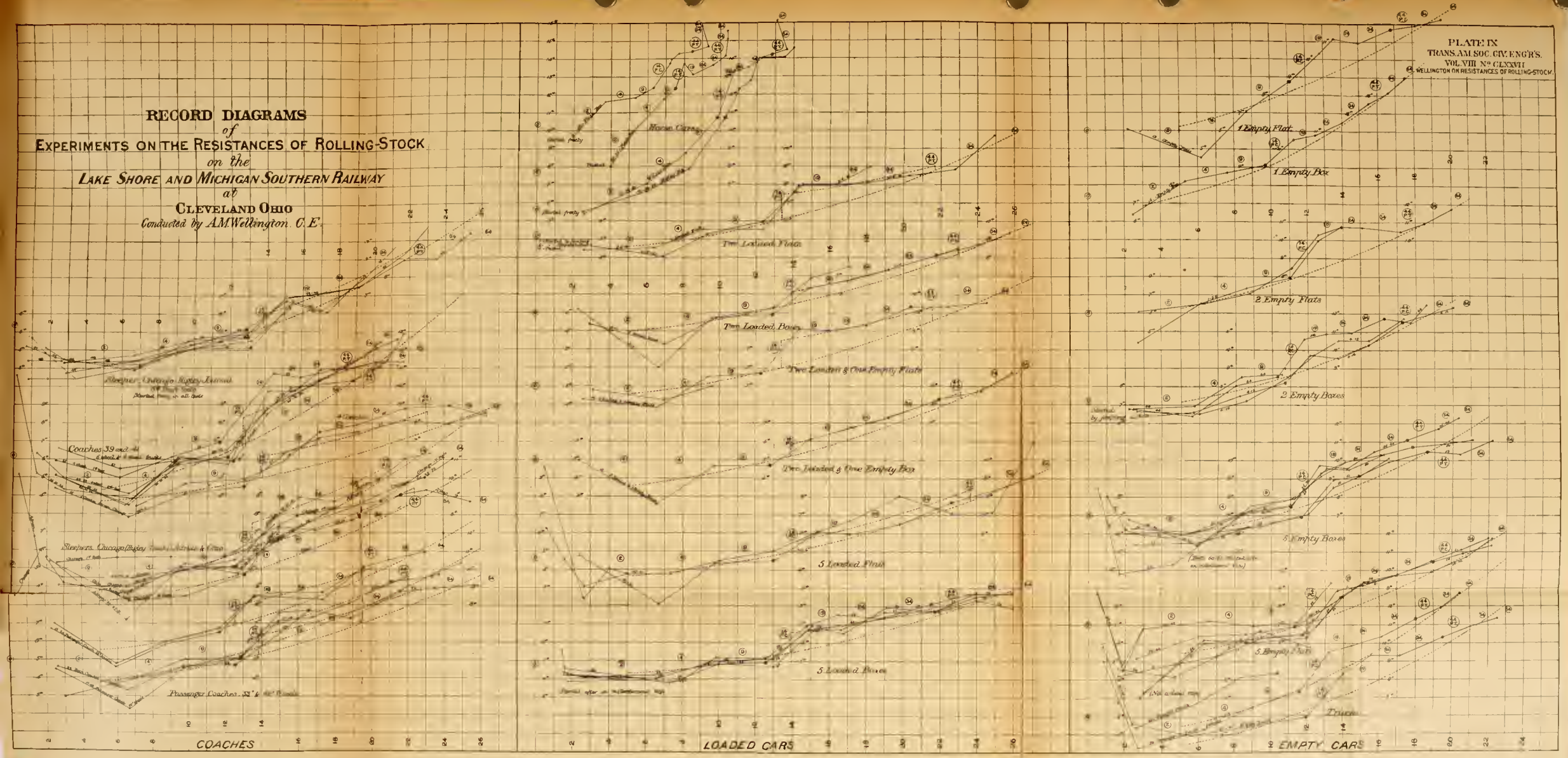
The same data computed with allowances for sources of error, as explained below. (Figures in brackets are the same in both computations)

8.10	1.02	1.02	[1.38]	0.36	0.18	3 6
[11.34]	[2.00]	0.98	[1.38]	0.40	0.20	4.0
[16.92]	[4.44]	[2.44]	[3.57]	[1.13]	[0.226]	[4.52]
20.9	6.80	2.36	[3.38]	1.02	0.204	4.08
[23.55]	[8.65]	1 85	[3.63]	1.78	0.356	7.12

Explanation.—The cars in Tests 3-11 were started by a slight push from the engine, it being impossible for six men to start them by pinching and pushing. Notwithstanding this extraneous impulse it will be seen in Col. 4 that the average velocity between 0 and 2 (3.32 feet per second) was so low that the terminal velocity at 2 deduced therefrom (3.32 × 2 = 6.64 feet) is noticeably less than that deduced from the average velocity in the next 200 feet, viz : 8.05 feet per second. As this phenomenon appears at no other station in Col. 4 (such variation as there is being in the contrary direction), it can only be due to a *temporary* abnormal retardation at the beginning, continuing after, and in addition to, the impulse of the locomotive. The true velocity at 2 is evidently (by comparison with those below) about 8.10 feet per second, and the effect of this change is shown in Computation 2, from which, it is to be noted however, the effect of all initial retardation is wholly eliminated.

A second correction in Computation 1 has been made in the velocity at Station 14, the beginning of a 1° curve. The curve introduces a new source of resistance at that point which reduces the average velocity between 14 and 19 considerably below what it would be on a tangent. This is of course visible in the computed initial velocity at 14 (20.2 feet), which, except for the curve, would plainly be (by comparison with those above) about 20.8 feet per second. The effect of such a correction is visible in Computation 2, and proves that the apparent irregularities of the record diagrams outlined in Fig. 5 would be increased and not diminished by more exact computation, and are due to other causes.

RECORD DIAGRAMS
of
EXPERIMENTS ON THE RESISTANCES OF ROLLING-STOCK
on the
LAKE SHORE AND MICHIGAN SOUTHERN RAILWAY
at
CLEVELAND OHIO
Conducted by A.M. Wellington, C.E.



DIAGRAM

showing the

RESISTANCES PER TON OF AMERICAN ROLLING-STOCK

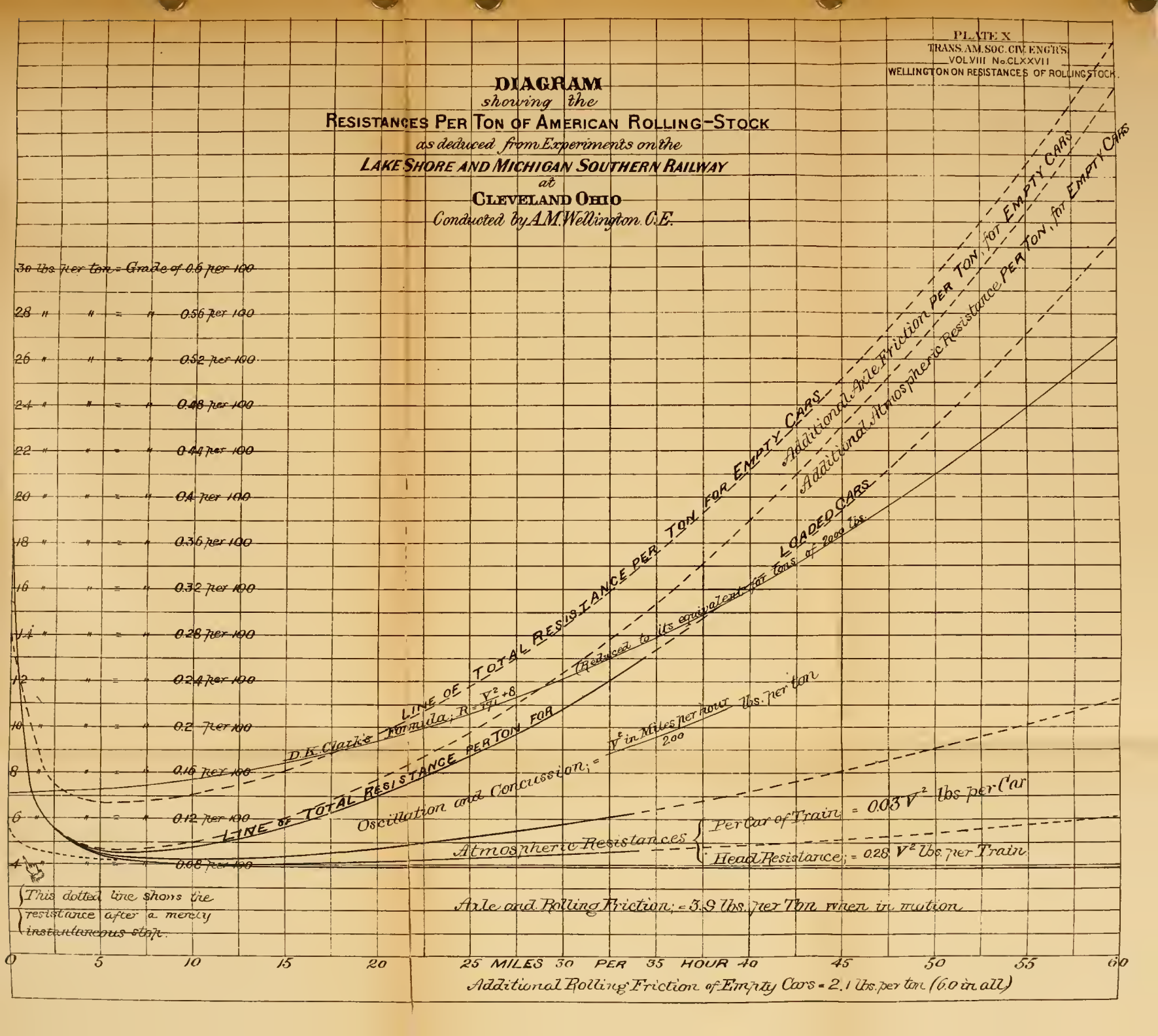
as deduced from Experiments on the

LAKE SHORE AND MICHIGAN SOUTHERN RAILWAY

at

CLEVELAND OHIO

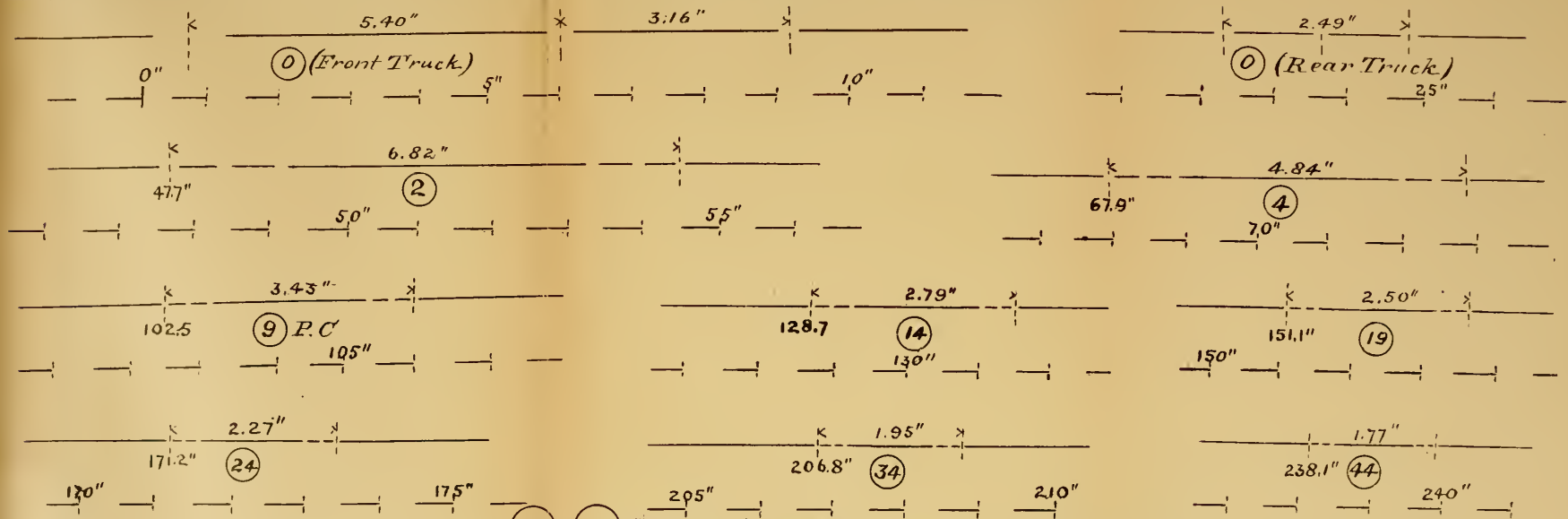
Conducted by A.M. Wellington C.E.



Telegraphic Record of Test No. 48

Sleeping Coach "Chicago" fitted with Higley Patent Roller Bearings. Total length of wheel base 59.2 ft. Wheel base of each truck 10.67 ft. weight 68000 lbs.

The upper lines give the telegraphic record of the passage of each wheel over each station. The lower line gives the synchronous telegraphic record of the seconds pendulum. Figures in circles show the stations at which records were taken, and the distance from the starting point in 100 ft. stations.



(54) & (64) *Telegraphic apparatus failed to work for this test*

Note: The recording instrument as now improved brings the car record and seconds record within 1/8 inch of each other affording much greater accuracy but has not yet been used.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CLXXVIII.

(Vol. VIII.—March, 1879.)

LIGHTHOUSE ENGINEERING AS DISPLAYED AT THE CENTENNIAL EXHIBITION.

By J. G. BARNARD, U. S. Army, Hon. Member of the Society.

As Chairman of Sub-committee on Lighthouses and Signals, organized for the object of aiding "in a proper representation of American engineering progress and practice at the Centennial Exposition, it now becomes my task to report on the exhibit of objects connected with above branches of engineering. It must be stated at the outset that Lighthouses and Signals being subjects *exclusively* of Government control, for which a Government organization—"The Lighthouse Board of the United States"—has been created, that board, of which the Secretary of the Treasury is *ex officio* the President, arranged and directed its own exhibit, leaving nothing for your Sub-committee to do.

A commission for this duty was appointed by the Lighthouse Board, consisting of Captain John L. Davis, U. S. N., member of the board; Brevet Brigadier General W. F. Raynolds, U. S A., Engineer of the Fourth Lighthouse District; Commander G. B. White, U. S. N., Inspector of the Fourth Lighthouse District; and Lieutenant A. G. Paul, U. S. N.

Owing to the small amount of money available ($6,000), the exhibit could not be as complete as the board desired it should be. Through this cause the *engineering* branch of the exhibit suffered more than any other. No models or drawings could be made *expressly* for the Exhibition, and the commission was constrained to content itself with the exhibition of such models, drawings and photographs as were already in possession of the board. It so happened that the iron work for the superstructure to an iron lighthouse for a marine site, on the tubular plan was nearly ready for erection upon the already constructed tube base on the reef at the entrance of New Haven Harbor, called the *South West Ledge*, while another set of iron work exactly similar was in construction at Baltimore for a work on Ship John Shoal in Delaware Bay.

It was the desire of the board to exhibit by full sized model, or by temporary use of some actual construction, a complete lighthouse, embodying some important *engineering* model, such, for instance, as one of our great iron skeleton tower lighthouses. Want of money prevented carrying out this design, but advantage was taken of the existence of parts of intended iron lighthouse structures to make an exhibit, which, if but an imperfect realization of the idea, enabled the board at least to exhibit an actual lighthouse. A wooden cylindrical substructure representing so much of the really important (in an engineering point of view) tubular member of the South West Ledge lighthouse as appears above the water was made, and on this the *real* superstructure, comprising the keeper's dwelling and store rooms, surmounted by the lens with its lantern, was erected. The light was shown on the night of the 4th of July, and from that date was maintained until the close of the Exhibition, with the same regularity and under the same rules as if it had been an actual sea-coast light, the keeper residing in the structure. But the real engineering significance of the kind of construction of which this exhibit was the type was quite undeveloped, the *tubes* which form their principal member being specially designed for sub-aqueous sites covered by considerable depths of water. These engineering features will be alluded to in another place.

Passing by for the present all other objects, I come at once to the models exhibited. The following is a list (transcribed from the report to the Lighthouse Board of Lieutenant A. G. Paul, U. S. N.) :

CLASS I.

No. 1. Model of the caisson and coffer-dam used in building the foundation for Spectacle Reef Lighthouse, Straits of Mackinac.

No. 2. Model of Spectacle Reef Lighthouse at entrance to the Straits of Mackinac in Lake Huron.

No. 3. Model of Brandywine Shoal Lighthouse on Brandywine Shoal, Delaware Bay.

No. 4. Model of Coffins Patches (*i. e.*, Sombrero) Lighthouse. An iron pile structure on the Florida Reefs.

No. 5. Model of Sand Key Lighthouse, on a small sand and shell island in the Florida Reefs, 7¼ nautical miles from Key West, Fla. An iron pile light house 121 feet from base to focal plane.

No. 6. Model of lighthouse at Chicago, Ill. An iron tower on the north pier of Chicago Harbor, Lake Michigan.

No. 7. Minot's Ledge Lighthouse, on the outer Minot, Boston Bay.

No. 8. Model of cribwork for foundation of South West Pass Lighthouse, mouth of the Mississippi River.

Besides these models, pictorial views, litho or photographic, of the following works were exhibited (list copied from Lieutenant Paul's report) :

No. 1.	Currituck Beach Lighthouse, N. C.		
" 2.	St. Augustine	do.	Fla.
" 3.	Race Rock	do.	Long Island Sound,
" 4.	Cleveland, Ohio,	do.	Lake Erie.
" 5.	Piedres Blancas	do.	California.
" 6.	Ship John Shoal	do.	Delaware River.
" 7.	Hunting Island	do.	S. C.
" 8.	Thimble Shoal	do.	Hampton Roads, Va.
" 9.	First-class lighthouse with steam fog signal.		
" 10.	Screw-pile river and harbor lighthouse.		
" 11.	Sand Key Lighthouse, Fla.		
" 12.	Alligator Reef	do.	"
" 13.	Pigeon Point	do.	California.
" 14.	Do. do.	do.	do.

No. 15. Craighill Channel Lighthouse (Front), Chesapeake Bay.
" 16. Do. do. do. (Rear) do.
" 17. Fort Sumpter do. S. C.
" 18. Lighthouse tender.
" 19. Cross Point Lighthouse, Lake Michigan.
" 20. Fowey Rocks. do. Fla.
" 21. Day Beacon, Flower Reef, Long Island Sound.
" 22. Minot's Ledge Lighthouse, Massachusetts Bay.
" 23. Penfield Reef do. Long Island Sound.
" 24. Spectacle Reef do. Lake Huron.
" 25. Foundation for Cross Ledge Lighthouse, Delaware Bay.
" 26. Do. do. do. do.
" 27. Do. do. do. do.
" 28. Tybee Island do. Ga.
" 29. Old Field Point do. Long Island Sound.
" 30. Fowey Rocks do. Fla.

" 31. A large map, 17 feet by 19 feet, showing on it each light under the jurisdiction of the Lighthouse Board of all classes; each class can be distinguished by a glance at the chart, the size of the red circular spot denoting the order and range of visibility. By the showing on this chart, the following list of the different orders can be seen:

First	46
Second	28
Third	67
Fourth	190
Fifth	125
Sixth	179
Stake*	280
Reflectors and Lightships	38
	953

* By the term "stake" is denoted a class of lights peculiar to the United States, and of recent introduction. They are for aiding the navigation on the Mississippi and its two principal tributaries, the Missouri and the Ohio, variability of the channels of which forbid permanent structures. They consist of a lantern suspended from a post or wooden scaffolding easily removable, and generally called a "stake," on the banks, the position of which may be shifted to correspond to the shifting of the channels. At date of last Annual Report of the Lighthouse Board for 1878, there were on the Ohio 244 "stakes" and 12 "floating" lights; on the Missouri, 34; on the Mississippi, above St. Louis, 155; below, 193; or 626 stake lights in all. These "beacon-lights," says the report of the board, "continue to give great satisfaction to those interested in river navigation, and may now be regarded as indispensably necessary.

I proceed to describe the peculiar engineering features of the works represented by the models and pictures.

The lighthouse on Minot's Ledge is the most important *engineering* work that belongs to our lighthouse system ; and indeed it ranks, by the engineering difficulties surmounted in its erection, and by the skill and science shown in the details of its construction among the chief of the great *sea-rock* lighthouses of the world.

"Minot's Rocks—or, as they are generally designated, 'the Minots'—lie off the southeastern *chop* of Boston Bay. . . . These rocks or ledges, with others in their immediate vicinity, are also known as the 'Cohasset Rocks,' and have been the terror of mariners for a long period of years ; they have been, probably, the cause of a greater number of wrecks than any other reefs or ledges upon the coast, lying as they do at the very entrance to the second city of the United States in point of tonnage, and consequently where vessesls are continually passing and repassing. The Minots are bare only at three-quarters ebb, and vessels bound in, with the wind heavy at northeast, are liable, if they fall to the leeward of Boston Light, to be driven upon these reefs. The rock selected for the site of the lighthouse is called the 'Outer Minot,' and is the most seaward of the group. At extreme low water an area of about 30 feet in diameter is exposed, and the highest point in the rock is about 3½ feet above the line of low water. It is very rare, however, that a surface greater than 25 feet in diameter is left bare by the sea. The rock is granite, with vertical seams of trap rising through it."

This work is one of peculiar engineering interest. The site had been occupied by an iron skeleton lighthouse, built (1848) by Captain W. H. Swift, of the United States Topographical Engineers, and carried away by the great storm of 14th, 15th, 16th, 17th of April, 1851. The history of this work, and of the catastrophe which befell it, is briefly given in the article, *Lighthouse Construction*, in Johnson's Cyclopedia.

The structure of which the model was exhibited succeeded the work just alluded to.

The difficulties of the work will be best appreciated from the following statement of the engineer:*

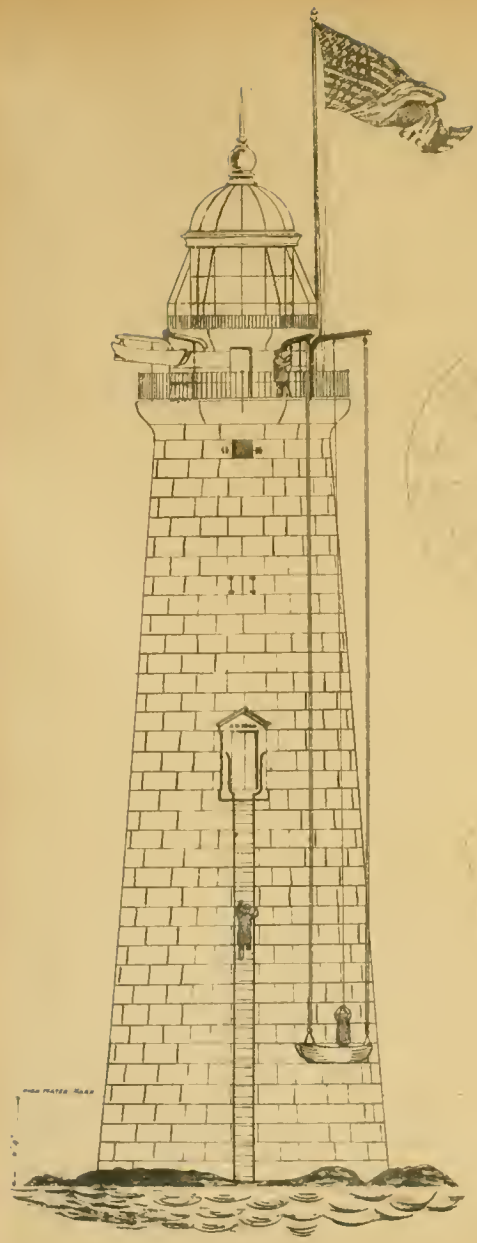
"It was a more difficult work of construction than either the Eddystone, the Bell Rock, or the Skerryvore, for the Eddystone was founded all above low water, part of its foundation being up to high-water level. The foundation of the Bell Rock was about 3 feet above low water, while

* In a succeeding number of the "Transactions" will be found the only connected "memoir" left by the engineer, the late Lieutenant-Colonel B. S. Alexander (Brevet Brigadier-General U. S. A.), on the history of the construction of this work.

the Skerryvore had its foundation above high-water level; whereas a good part of the foundation of the Minot's light was below low water. There had to be a combination of favorable circumstances to enable us to land on the Minot Rock at the beginning of that work—*a perfectly smooth sea, a dead calm, and low spring tides.* This only could happen about six times during any one lunation—three at full moon and three at the change. Frequently, one or the other of the necessary conditions would fail, and there were at times months, even in summer, when we could not land there at all. Our working *season* was from April 1 to September 15. Work was prosecuted with all possible diligence for more than three years before a single stone could be laid. *The* difficulty was to cut the foundation rock into the proper shape to receive the foundation stones, and then to lay these stones."

Both an elevation and a vertical section are given herewith. The shaft is purely conical, the limited bottom area forbidding the expansion required for the *tree-like* spread to the base—which is usual in European sea-rock lighthouses.

The structure is solid (around a central well) up to the level of the entrance-door. Above that there is a hollow cylindrical space, 14 feet in diameter, arched over at the level of the cornice. This space is divided into five stories by four iron floors. These five compartments, and a sixth, immediately under the lantern, constitute the keeper's rooms, store-rooms, etc. On Plate 12 is shown an elevation and vertical section of the tower, and also horizontal sections showing the "bond" of the stonework of the solid parts, also of the Eddystone, Bell Rock, Skerryvore and Wolf Rock towers. There is besides a plan of the Rock itself as prepared to receive the foundation stones, in which the numbers (with the plus or minus sign) indicate the *level* of the respective areas—*e. g.* (—1′ 3″) indicate 1 foot 3 inches *below* the *zero;* which zero, however, is itself 1′ 9″ above mean low water. The small black disks mark the holes for the iron shafts of the old structure. In these, continuous dowels were inserted, which ascended as far as the twelfth masonry course. In the horizontal section the gun-metal dowels are marked, by which each course of the solid part was secured to the one above or beneath. The courses of the shell above the solid part were each *joggled* by a middle annulus with the course above. The following details are given for reference.



ELEVATION

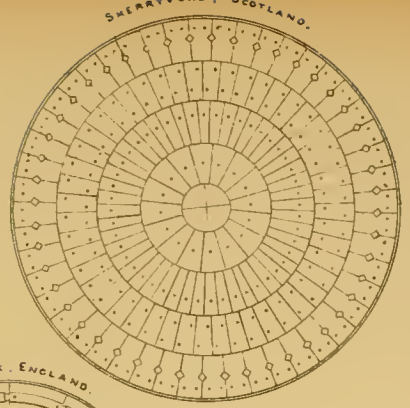


Fig. 3.
3d Course.

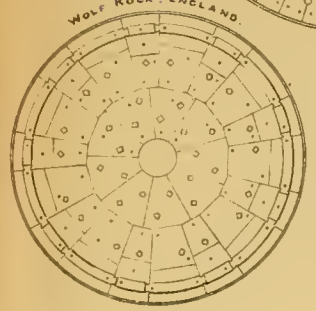
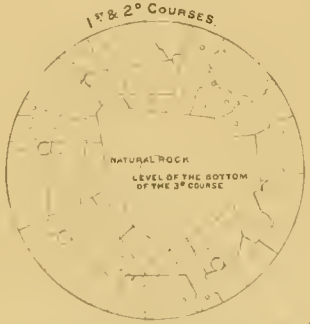


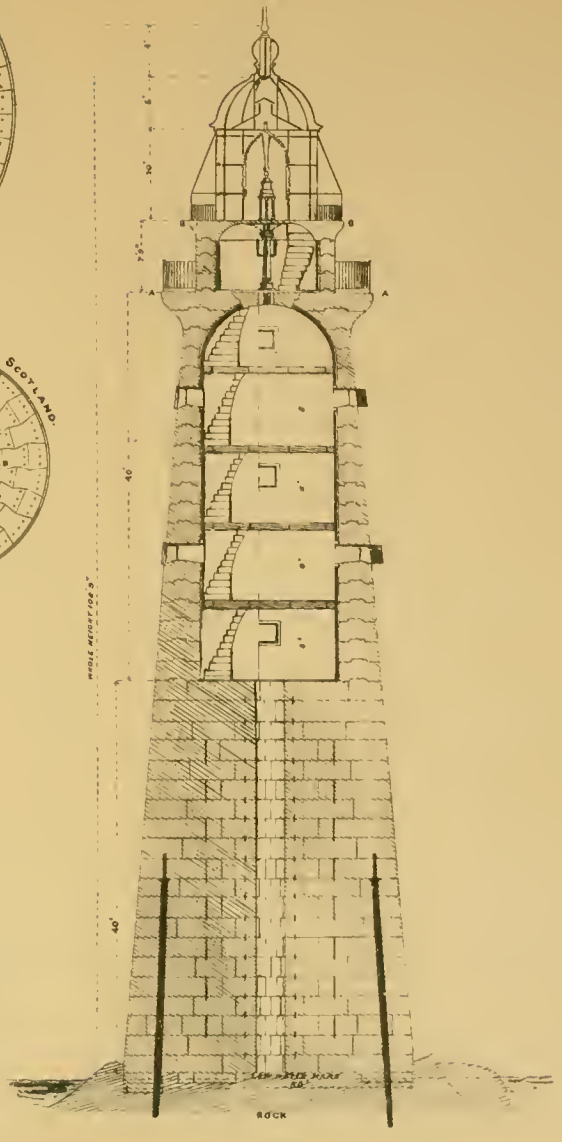
Fig. 1.
PLAN OF ROCK AS PREPARED TO RECEIVE THE FOUNDATION STONES
(01 IS 1'9" ABOVE MEAN LOW WATER

Fig. 2
1st & 2d Courses.



The full lines represent the stones of the second course the dotted lines represent the seven stones of the first or lowest course

SCALE $\frac{1}{8}$ INCH = ONE FOOT



SECTION

MINOT'S LEDGE LIGHT HOUSE

WITH COMPARATIVE SECTIONS OF OTHER

SEA ROCK LIGHT HOUSES

The first blow was struck on the ledge Sunday morning at sunrise, July 1, 1855 :

Hours worked on ledge in excavating foundation pit during 1855...	130 hours.
Hours worked on ledge in excavating foundation pit during 1856...	157 hours.
Hours worked on ledge in excavating or laying four stones during 1857	130 h. 21 m.
Hours worked on ledge in excavating pit and in laying six courses during 1858	208 hours.
Hours worked on ledge in laying twenty-six courses of stone during 1859	377 hours.
	1,102 h. 21 m
No. tons of rough stone	3,514
No. tons of hammered stone	2,367
No. stones in lighthouse	1,079

The first stone was laid July 9, 1857; the lowest stone was laid July 11, 1858 :

Whole height from bottom of lowest stone to top of pinnacle	114′ 1″
Height of focal plane above lowest point	96′ 1″
" " " mean high water	84′ 7″
Diameter of third (or first full) course	30′
" top of twenty second course (solid part)	23′ 6″

Observations made at Boston Lighthouse from June 7 to October 27, 1847, furnish the following results :

Rise of highest tide	11 ft. 7 in.
Mean rise and fall of tides	9 " 4 "
" " " spring tides	10 " 8 "
" " " neap "	8 " 3 "

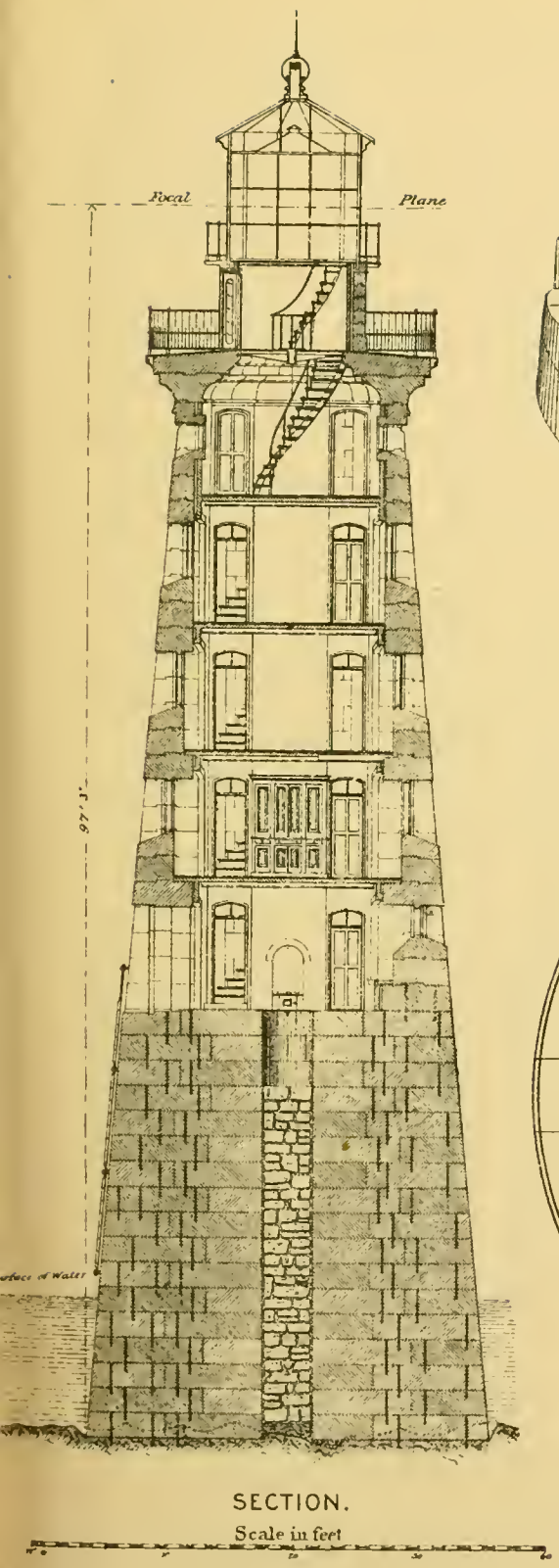
Besides the Minot's but one other specimen of that kind of lighthouse construction is offered by the Lighthouse Establishment of the United States. That one (Spectacle Reef), of which the model of the caisson and coffer dam used in building the foundation, and of the finished structure, were exhibited. This is not properly a "*sea*-rock" lighthouse, nor are the destructive agencies it has to encounter *sea-waves*, but chiefly *ice packs*.

It stands upon a reef in the northern part of Lake Huron, off the eastern end of the Straits of Mackinac. It is built upon the southern extremity of the most northerly of two shoals (limestone rock *in situ*, covered with a layer of about two feet in thickness of boulders), so situated with reference to each other as to suggest the name, "Spectacle

Reef." The least depth of water on the shoal is about 7 feet, but at the site selected for the lighthouse the rock was found at a depth of 11 feet. The nearest land is the southeasterly point of Bois Blanc Island, distant 10½ miles. The greatest exposure to waves is to the southeastward, from which direction the seas have a range of about 170 miles. Were there no other destructive agency, sufficient stability would have been easily secured. But, under certain meteorological conditions, currents having a velocity of from 2 to 3 miles per hour are developed here, which during the inclement season serve to move to and fro ice-fields which frequently have an area of thousands of acres and a thickness of as much as two feet. This ice, formed in fresh water, is of great solidity, and when moving in the mass, and with the velocity named, has a "living force" which is almost irresistible. The aim was to oppose to it a structure against which the impinging ice would be crushed and packed till it should ground upon the shoal itself, and form a barrier against subsequent action. To give some idea of the necessity for this, it may be mentioned that in the spring of 1875 the ice was piled up against the lighthouse to the height of 30 feet above the water, or 7 feet above the sill of the doorway, which is 23 feet above the lake, and when the keepers went to the station to exhibit the light (not in operation during the winter) they were able to obtain entrance to the tower only by first cutting a passage through the pile of ice referred to.

The first step was to surround the site of the proposed tower with a "pier of protection"—a crib-work (filled with ballast-stone) 92 feet square, enclosing an interior opening 48 feet square. This furnished a landing-stage and area for quarters for workmen, and secured still water in which to place the coffer-dam. The coffer-dam was cylindrical in form, 36 feet in diameter (exterior), and made of staves 4 inches thick, 6 inches wide, and 14 feet long. These staves, carefully jointed, were held together by three iron bands or hoops on the outside, and to enable it to withstand the pressure from the outside, when empty, the dam was braced and stayed in the strongest manner against a centre-post, the axis of which was coincident with the axis of the cylinder. The details by which the coffer-dam was built at the surface of the water, lowered, and, by then driving down individual staves wherever necessary, fitted to the irregular bottom and the joint calked, cannot here be given.* After ex-

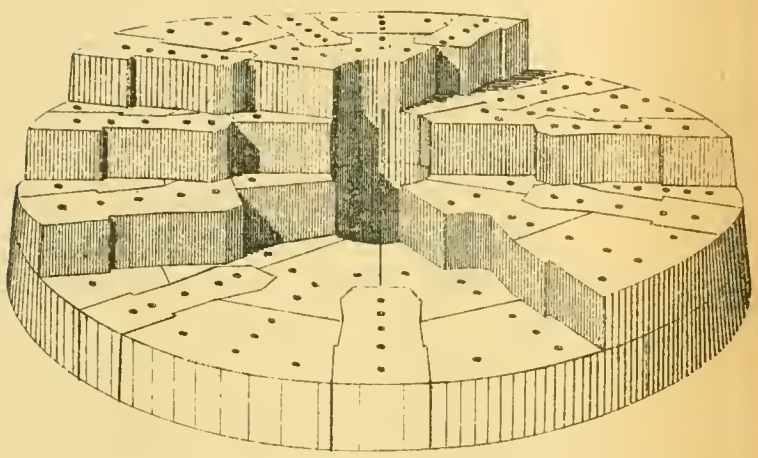
* The engineer, Gen. O. M. Poe, a member of the Lighthouse Board, is engaged in preparing for publication by the Board a full account of this work.



SECTION.

Scale in feet

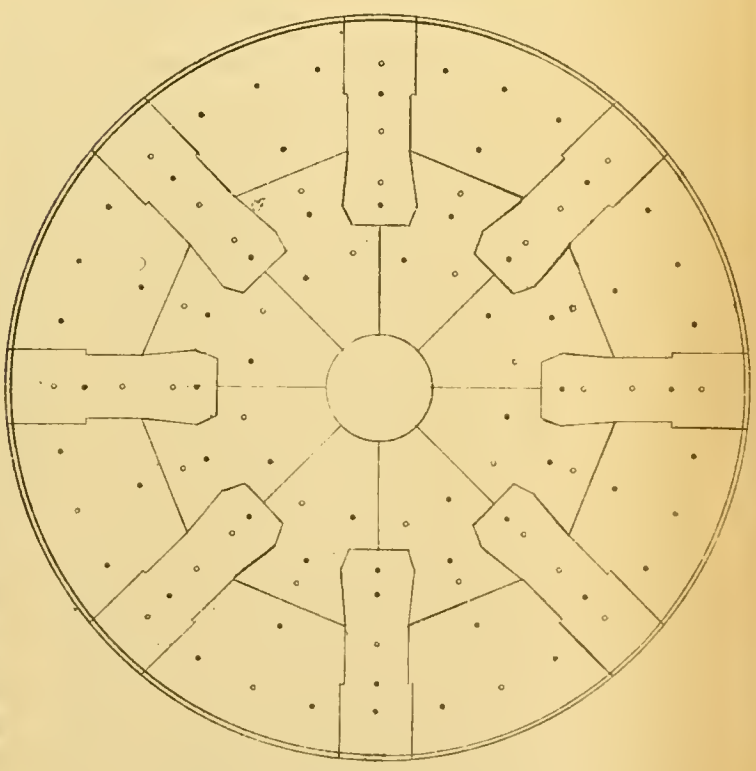
DETAILS OF MASONRY.



PERSPECTIVE VIEW OF COURSES 14, 15 & 16.

Scale

12 6 0 2 4 6 8 10 12 14 16 18 20 feet



GROUND PLAN OF COURSE 14.

LIGHT-HOUSE AT SPECTACLE REEF,
LAKE HURON.

hausting the water, levelling the bottom, and laying the first course, the annular space between it and the inside of the cylinder was filled with concrete, thus making an artificial bottom which was perfectly water-tight. The exterior of the tower (see Plate XIII) is a frustum of a cone, 32 feet in diameter at the base and 18 feet at the spring of the cornice 80 feet above the base. The cornice is 6 feet high, and the parapet 7 feet. The focal plane is 4 feet three inches above the top of the parapet. Hence the entire height of the masonry above the base is 93 feet, and of the focal plane 97 feet 3 inches. The base is 11 feet below the surface of the water, and the focal plane 86 feet 3 inches above the same surface. The tower is solid to a height of 34 feet. Above this it is hollow, and divided into five stories or rooms, each 14 feet in diameter. The courses (of uniform thickness of 2 feet) are *bonded* as represented; they are dowelled where solid and joggled where annular, very much as at Minot's, which work, indeed, served as a model,

The light was first exhibited June 1, 1874, work having been commenced May 1, 1870. The aggregate *working* time was really less than twenty-four months ; cost, $375,000.

The history of Mr. Alexander Mitchell's invention of the screw-pile, as also of its many subsequent uses for marine structures, are well known to professional engineers. As a means of lighthouse construction on sandy or soft sea bottoms, it was first designed, and the first construction of this kind—*the first screw-pile lighthouse*—was built by the inventor for the corporation of the Trinity House, on the Maplin Sand, at the mouth of the Thames. This interesting structure is fully described in Vol. VII., *Proceedings of the Institution of Civil Engineers.* Built in 1838, this work is still in perfect preservation. The iron tower on Minot's Ledge, though in other respects undistinguishable, was not a *screw-pile* structure, since its piles or angle-posts were set in holes drilled in the rock.

The first screw-pile light of the United States was erected by the late Col. Hartman Bache, U. S. E., near the mouth of Delaware Bay, 8 miles from the ocean, and very much exposed, on a shoal covered with 6 feet low water spring tides, but over which rise spring-tides 13½ feet and storm tides 18 feet. A lighthouse built here in 1827–28 by Mr. Strickland of Philadelphia (plan not known to writer) was very soon "demolished by action of the sea." A design was then proposed in the bureau of topographical engineers for a work built "on a mole of break-

water-stone." This was abandoned, because the superstructure, "being built upon breakwater stone thrown at random on the bottom, would by unequal settling be liable to fracture; and it was doubted whether heavy masses of masonry, raised upon such a base, ever proved entirely satisfactory;"* and some progress was made (1839) in the collection of stone and the building of a caisson, by means of which a masonry foundation was to be started from the bottom. This plan, too, was abandoned, and in the years 1847–50 the existing lighthouse was erected, which stands yet in good condition, though not without having required reinforcement to its ice-breaker. A peculiarity distinguishing it from all other screw-pile structures is due to its exposure to the powerful action of ice borne to and fro by the violent ebb or flood currents. The light-tower proper is surrounded by an *ice-breaker;* itself an iron screw-pile structure having no connection with the lighthouse, though the two *seem* to form one building. (See Plate XIV.) The *ice-breaker* has since this delineation been much enlarged, and its top floored over so as to form an esplanade.)

For the numerous sand shoals in the great bays or off the southern coast of the U. S., which needed to be marked by lights, the screw-pile system, thus introduced, seemed especially applicable, and its extension has been very rapid; more than fifty such structures now exist, some of great magnitude and importance, but far the greater number for harbor or bay lights. Sand Key (1853), Carysfort (1857), Sombrero (1857), Alligator Reef (1873), all "first-order."

Models were exhibited of the Sombrero (Coffins Patches) and the Sand Key lighthouses; and a pictorial exhibit of that on Alligator Reef, which may be considered typical of the class. The nearest land, Indian Key, is 4 miles to the westward. A temporary platform was erected upon this site, supported on mangrove piles shod with iron, and driven five feet into the bottom in partially indurated coral rock. A small landing-wharf or jetty for receiving materials was also built in connection with this platform. The platform being completed, the nine heavy cast-iron foundation-disks were accurately placed at the centre and angles of the octagon, the surface of the coral rock being first smoothed and leveled for each disk. By an ingenious system of gauges the disks were set in their positions, with their proper relative

* A light has been recently (1875) thus founded on a shoal—the "Cross Ledge"—15 miles above the Brandywine.

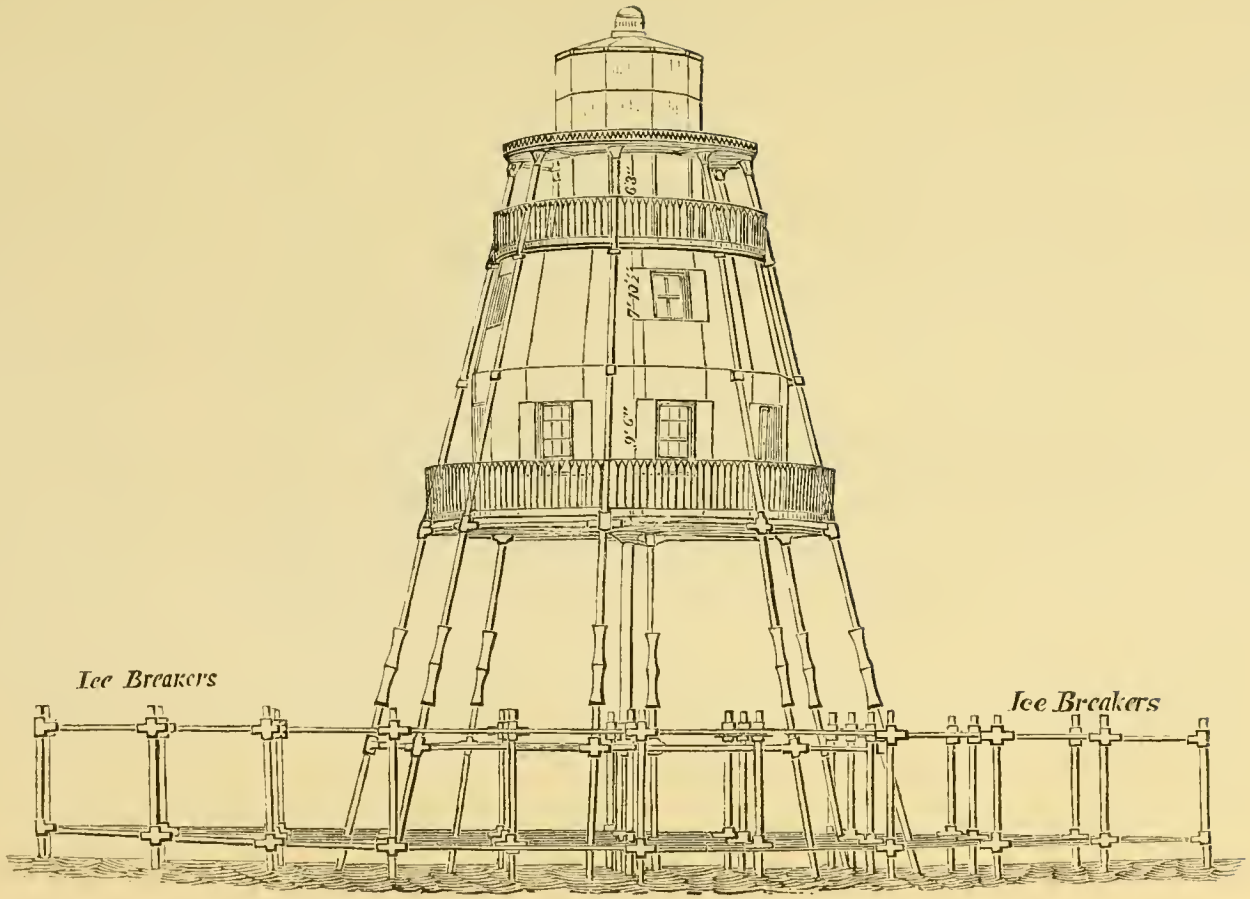


PLATE XIV. BRANDYWINE SHOAL.

distances—a work of very great difficulty. The foundation-piles pass through the centres of the disks, and rest by shoulders upon them. These piles are of solid wrought iron, 26 feet long and 12 inches in diameter, and pointed at their lower ends, the upper ends being lathe-turned and cut off square. The pile-driver used in driving them carried a hammer of 2,000 pounds, which was hoisted by a portable steam-engine. The piles were kept accurately vertical during the driving by purchases attached to their heads. The penetration into the coral at each blow of the hammer with an average fall of 18 feet, varied from ½ inch to 1½ inches, and about 120 blows brought the shoulder of the piles into contact with the disks, giving them a depth in the coral limestone rock of 10 feet. The piles being driven, their tops were cut off to a horizontal plane 11 feet above the water, and the cast-iron sockets which fit on their heads were put in their places. The second series, consisting of nine solid wrought-iron pillars 10 inches in diameter, was inserted in these sockets, etc.

The work now in progress on Fowey Rock (shown in Plate XV), as it will be when completed, is presented on the extreme northern extremity of what is called the Florida Reef, is intended to be on the very reef itself; a substitute for the existing shore (Cape Florida) light. Having rather a more open exposure to the *ocean* waves (coming from N. E. from the Atlantic), to this work has been given a greater spread of base, and it is in other respects planned for enduring heavier strains than the first mentioned. The lower course of (vertical) foundation piles has, at the present date, June, 1877, been fixed on the site; the superstructure will be added during the coming season.*

Although not included in the exhibit, the existing and designed actual screw-pile towers for Ship Shoal (Plate XVI), and Trinity Shoal should be noticed here.

Ship Shoal and Trinity Shoal, Gulf of Mexico, are submerged sand-banks, lying dangerously in the way of navigation between the mouth of the Mississippi and Galveston. A screw-pile structure was erected 1858–9, on the first, under the direction of the late W. H. Stevens, then an officer of engineers. Situated (lon. 91.04° W., lat. 28°55′) about five nautical miles from the nearest land, in 15 feet of water, this work has thus far resisted the force of the sea and of the wind (sometimes amounting to

* This lighthouse was completed and lighted June 15th, 1878.

hurricanes). Some trouble has been caused from the erosion of the sea bottom, and a covering of quarry stone is designed to be applied over a considerable area. A similar work on Trinity Shoal was commenced in 1873, but the preliminary staging which had been erected was carried away in a severe gale, and the work has not been resumed; a lighthouse (the *Timbalier*) in the sheltered waters of Timbalier Bay, 60 miles west of the Southwest Pass of the Mississippi, has been recently (1874) rebuilt on this model.

The Southwest Pass lighthouse (Plate XVII) is an instance in which iron skeleton towers are resorted to for important land sites where the soil offers no adequate support for a masonry structure. A model of the foundation grillage was exhibited. Plate XVII shows an elevation of this structure and its connection with the foundation. The two upper courses of grillage timber were omitted in the construction.

The soil, recent alluvial, made up of the sedimentary deposit of the river, is of clay, very fine sand, and vegetable matter; very yielding (*i. e.*, *plastic*, and in that sense "compressible"), and hence incapable, by itself, of bearing a heavy superstructure. But that the site is not *quite* so mere a quagmire as may be supposed, the erection on a grillage, in former years, of a brick tower is proof. This, it is true, has settled greatly,* but its abandonment had otherwise become imperative through encroachments of the sea. This beacon should be the prominent landmark of this portion of the Gulf, and a first-order light, 128 feet above sea-level, was designed. A commencement was made by driving wooden piles over an area 60 feet in diameter, 3½ feet apart, in rows of like distance, to a depth of fifty feet. Then another series of piles in the centre of each square thus formed. The first series was cut of at 2′ 6″ below low water, and the second series at 1′ 6″ below. A reticulation of grillage timbers was laid on the heads of the first series and carried up for four or more thicknesses, the intervals or free space being packed with concrete, then concrete alone, to make a thickness of about eight feet. On the surface of this were secured, or bolted, the iron socket-disks from which start the nine (eight external and one central) shafts of the skeleton. The light was first exhibited in the beginning of 1873, two or three years having been occupied in the construction.

* Besides great vertical settlement, the tower is said to have *leaned* 2½ feet. It must have been built between 1840 and 1850.

LIGHT HOUSE ON FOWEY ROCKS, FLA.

The lighthouse actually erected on the Exhibition grounds, as has been stated, had for its superstructure the iron work prepared for the S. W. Ledge, New Haven Harbor.

The accompanying Plate XVIII exhibits so much of the structure as appears above water.

The site is rock, submerged in eleven feet of water (low tide). A ring breakwater of quarry stone (rip-rap) was thrown about the site; the rock levelled by a layer of concrete, and the lower horizontal section of the cast iron tube set by aid of a diving bell, the separate sections of which were united into complete rings by bolting together the flanges.

The tubular foundation just described was designed by Major Geo. H. Elliot, when Engineer-Secretary of the Lighthouse Board,* for sites where the prevalence of ice would be inimical to iron-pile structures. The Craighill Channel (approach to the port of Baltimore) front light represents another of these structures, having, however a very different superstructure.

It is described as follows:

"The cast iron tube, between high and low water, and for at least 2 feet above and below the space included between those limits, is 2 inches thick, the other portions to be 1¼ inches thick. The tube consists of two parts, the lower portion, for a height of 12 feet, being in the form of a frustum of a cone 30 feet in diameter at the base, 24 at the top; the upper portion is a cylinder of the same diameter as the top of the frustum of the cone to which it is joined. The tubing is cast in sections, each section being divided into twenty-four parts, joined together through flanges by wrought iron bolts. The lower section of the tubing is bolted to a grillage or flooring consisting of four layers of timber each 12 inches thick, forming a caisson, which is sunk in position below the bottom of the bay by filling it with concrete. It was found that for a depth of 22 feet the soil is the softest kind of mud—so soft, in fact, that an ordinary pile on end would penetrate 20 feet under the action of its own weight. Below this, alternate thin layers of sand, mixtures of sand, mud and shell were found to a depth of 20 feet more, with no signs of a solid foundation within 60 feet of the water's surface. It was therefore determined to drive a cluster of piles, cut them off at a level of 27 feet

* A structure on this plan had been first erected by Col. (Bvt. Brig. Genl.) Duane, the Duxbury pier light, near Plymouth.

below the surface of the water, and lower the caisson on them by filling it with concrete ; and in order to protect the lighthouse from lateral vibration and the scour of the tides, to build a rip-rap wall of loose stones around it."

"A structure of the same kind, resting likewise upon piles driven into a sand and clay bottom, has been placed on Ship John Shoal, Delaware Bay, which, in external appearance, will be the same as the S. W. Ledge lighthouse. The manner of constructing and founding the tube of this work is thus described by the Engineer, Gen. W. F. Raynolds :

"The construction was in all respects according to the specifications, excepting that the wooden bottom of the iron caisson was given one foot greater diameter than called for. The shoal was dredged until we had about 17 feet at low tide (originally 8 feet). In this basin the piles called for were driven, each pile estimated capable of bearing 30 tons. A U shaped platform was built around the piles and a sheet piling guard opposite the opening; the side of platform opposite the guard was also faced with sheet piling, thus cutting off both ebb and flood tide, and making a still basin in which to work.

"A traveler or truss on wheels was thrown across between the arms of the U ; on this was placed a circular saw or vertical shaft run by steam, by which the piles were cut off 16 feet below the level of low tide. A mistake was made in suspending this saw by a wire rope, as the level of the saw was slightly changed by the twist, rendering it necessary to block up some of the piles nearly an inch to get the heads perfectly level.

"The difficulty in sinking the caisson was this : An ordinary tide rises 6 feet ; storm tides, 10 feet. Hence we had to make it secure in 26 feet of water, while on the bar over which it was to be carried there was only 10 feet. A wooden caisson was built on the projection of the bottom of the iron caission. Concrete was then placed in the iron caisson until the whole was drawing just 10 feet. Then after getting the caisson into position by letting water into the wooden caisson (between it and the iron), which did not take over ten minutes, it was sunk to 18 feet. It was floated into position at high tide, and the fall of the tide would have brought the bottom of caisson on the heads of the piles.

"The iron caisson was 24 feet in diameter. Inside of it a box was built 17 feet in diameter. The final sinking and securing was effected by filling this box with gravel, which was easily done between tides.

FIRST ORDER LT. HOUSES
SHIP SHOAL & TIMBALIER,
GULF OF MEXICO.
8th District.

PLATE XVI
TRANS. AM. SOC. CIV. ENG'R'S.
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BARNARD ON LIGHTHOUSES.

The outside caisson was held in position by vertical rods. It was taken away as soon as possible by unfastening these rods and making two vertical cuts through it with saws.

"I may add that the spaces between the piles were filled up with small stone to the level at which they were cut off, and after sinking, a spirit level on the top of the iron caisson, showed it was horizontal."

The light-towers of terra firma, even (if the site be elevated) for the most important lights, require only so much elevation as will prevent obscuration by surrounding objects, and in general present no features of engineering interest. If, however, the site be very low, a light of the first order, demanding an elevation of at least 150 feet, the structure appeals to the engineer not only for accurately calculated elements of stability, but for well-devised interior arrangements. One of the most recent of these structures, Body's Island lighthouse, N. C., was not represented at the Exposition (see Plate XIX). "A secure foundation was obtained by excavating until a bottom of hard, clear sand was reached at 7 feet below the surface. On this was laid a grillage of timbers 6″ by 12″, placed at right angles to each other in two layers; then followed one course of dimension stone 18″ thick; over this coursed rubble laid in large blocks, thorougly breaking joints, and all grouted with 1 part Portland cement and 2 of sharp sand. From this foundation rises the base of the tower, the frustum of an octagonal pyramid with plinth and cornice. The interior 'well' of the tower is lighted by five windows. Access to the watch-room is had by eight sets of spiral stairways, the first seven of which make half the revolution of a spire, the eighth an entire revolution. These stairways are not attached to the tower walls, but are supported by the landings—semi-circular iron plates resting on I-beams and a corbelling projecting from the interior face of the tower. There is a hand-rail on each side, and the entire system of stairs belonging to each flight is kept rigid by making the carriers of such a form that each baluster firmly bolts together three contiguous ones." The arrangement of the stairs, by which the encumbrance of a central shaft containing a winding stair is avoided, the interior better lighted, and room gained, is an improvement introduced by Major Elliot.

The height of tower from base to focal plane is 150 feet. Plate XIX exhibits an elevation, vertical section, and several horizontal sections.

The St. Augustine (Fla.) light, of which there was a pictorial exhibit, is of identical construction, and has the same height of tower.

A pictorial exhibit was presented of the lighthouse on Hunting Island, S. C. This represents a peculiar case.

The north point of the island is undergoing abrasion by wave action. The objects the light should subserve fixed the location *within* the possible future range of this abrasion. Hence it was determined to make a tower which can be taken down and removed in case of necessity, though the contingency was not deemed probable. The lighthouse is shown in Plate XX. "The 12-hundredweight iron panels of each horizontal section were cast of exactly the same size, so that each might occupy any position in its own section. The panels of the shell vary in thickness from 1½ inches (lowest section) to ¾ inch (highest). The flanges serving to connect the several tiers of plates and the plates of each tier with each other are smooth and true-planed surfaces; the holes in the flanges are drilled, and the bolts turned to neatly fit them. The base of the first tier of panels consists of a flange 3 feet wide. Of this flange the width of 1 foot 4 inches extends beyond the outside of the tower; this part contains the holes for the foundation bolts, which are strengthened by bosses and vertical knees extending upward to the top of castings. The top flange is 6 inches by 1¾ inches; the lower flange of the second section is 1 foot 2 inches wide. The top flange of this tier and the flanges of the third section are 6 inches by 1¾ inches. The flanges of succeeding sections are similar, with some slight variation of dimensions. The side flanges correspond in size with the top flange of each panel. All the horizontal flanges have strengthening knees on each panel, 2 feet high and 1½ inches thick, at equal distances apart. An interior lining of brick, 9 inches thick, is built in between the lower flanges. The whole structure rests on a concrete foundation 8 feet thick, to which the lower iron section is secured by 36 anchor bolts built into the concrete.

The Race Rock lighthouse (Plate XXI) presents a peculiar aspect of the problem of subaqueous foundations.

"The Race" is applied to what may be called the eastern water-gate to Long Island Sound, lying between the N. E. extremity of Long Island and Fisher's Island (off New London, Conn.). Little Gull Island, the Long Island *gate-post*, is marked by a light. The other gate-post (to maintain the simile) was Race Rock, three-fourths of a mile from the

FIRST ORDER
H. FOR S.W. PASS, LA.
9th District

PLATE XVII
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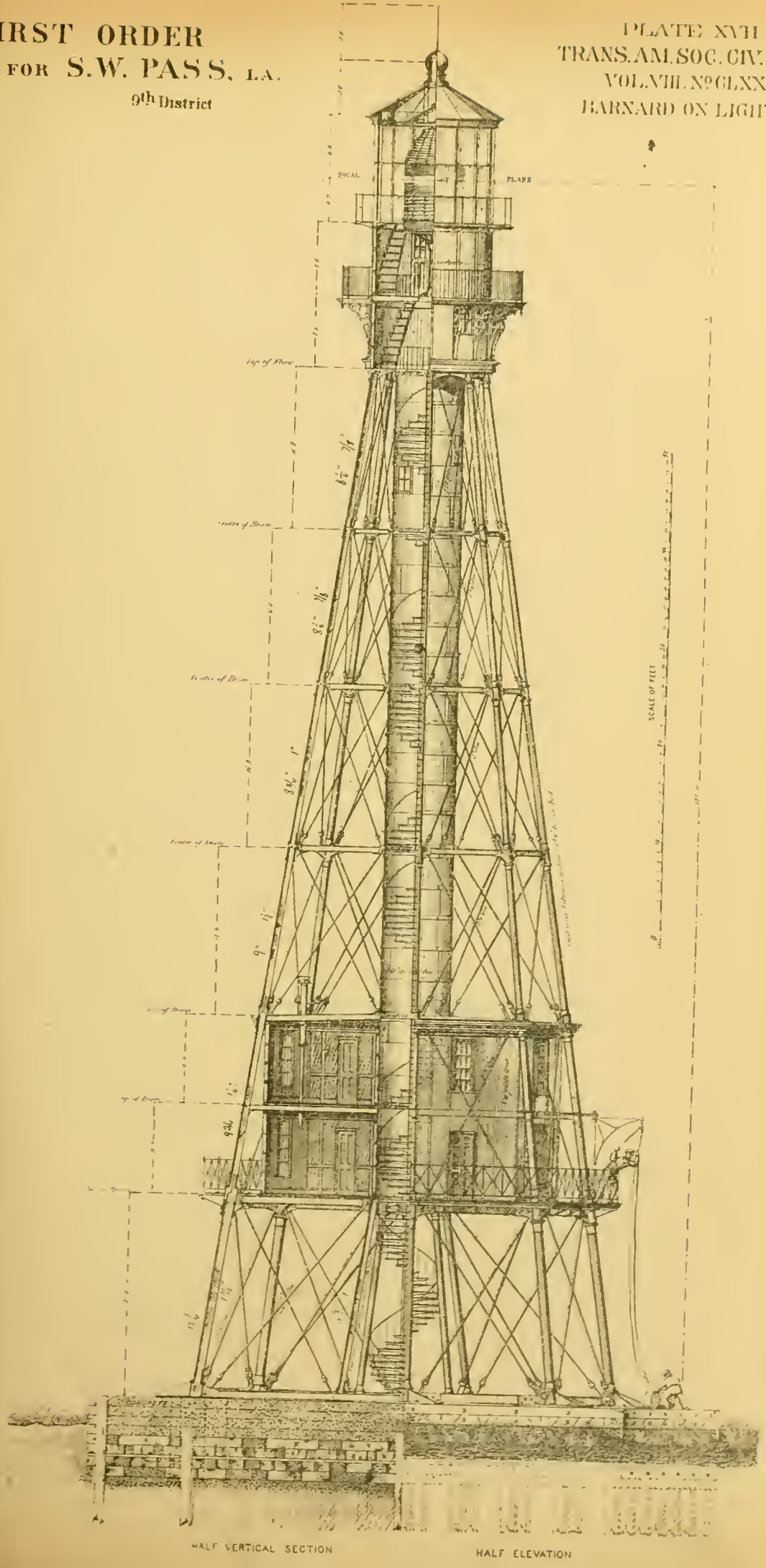
BARNARD ON LIGHTHOUSES.



S. W. point of Fisher's Island, an isolated submerged rock, or rather a huge boulder, surrounded by depths of 12 or 15 feet, low water, with 3 feet additional at high water. The tides (hence "The Race") flow with excessive violence, with but brief intervals of slack water. From the E. and S. E. the ocean wave finds no barrier save Block Island, and, therefore, violent wave-action was apprehended; moreover, *ice* from New London harbor and the marginal waters of the Sound is to be feared in winter. Hence, to form a rip-rap embankment (*a pierre perdue*) of oval form, 100 by 150 feet, well protected on its margins by blocks of eight or ten tons weight, was decided upon as the first step. This would be not only an immediate means of getting at the site, but a future protection against wave and ice violence. The interior of this embankment was then removed (better to have left it vacant in the first place), and the foundation of concrete (retained in form externally by circular bands of sheet iron each about two feet high) was brought up from the bottom by aid of the diver, who first accurately placed each successive band. It should be remarked that the natural bottom is of boulders compacted with gravel and sand, and therefore very firm.

In other cases of interaqueous construction, where the depth is not great, a simple *rip-rap* foundation of quarry stone is resorted to. The Penfield Reef (off Black Rock harbor, Conn.), of which a pictorial exhibit was made, is a case of this kind (see Plate XXII).

A more important engineering structure of this kind is exhibited by the work now in construction* on Stratford Shoal, Long Island Sound. In this case the rip-rap was thrown as a *ring*, the interior of the ring filled up with concrete laid subaqueously on the surface of the shoal, which was very compact gravel, covered with about six feet of water, low tide.

Plate XXII shows the general appearance of these structures.

In what precedes, only types of lighthouse construction involving features of engineering interest are presented. However interesting to those for whom the sea-coast illumination is the special duty, to the engineer in general the peculiarities of ordinary lighthouse construction are matters of little interest, and are not dwelt upon in this report.

For the same reason I pass over entirely the subject of *illumination*, and also that of *signals*. Both these subjects in their connection with

* Completed and lighted in 1877.

the Centennial Exposition have been fully reported upon to the Lighthouse Board by Lieut. A. G. Paul, United States Navy.* I therefore turn to the exhibits of foreign countries, and take the liberty of making a brief extract from Lieut. Paul's MSS. report:

"France appears to be the only government that has made any attempt to exhibit a complete condition of its lighthouse system, and, under the direction of the Ministry of Public Works, has put up a building, a large portion of which is devoted to lighthouse matters.

"Commencing with the country itself, we find that on the 1st of January, 1876, France (not including Algeria) had three hundred and seventy-nine lighthouses in position and working. This includes lightships and floating lights:

First order	45
Second "	6
Third "	31
Fourth "	33
Fifth "	254
Lightships and floating lights	10
	379

"In connection with these data several large books were sent over containing photographs of nearly all of the most important lighthouses; also a large chart showing the lights and the radius of visibility on it; and several books of reference, and some documents."

The following exhibits were made by model or by pictorial representation:

State of lighting and beaconing on the coasts of France.
Lighthouse of Cape Spartel (Morrocco).
" New Caledonia.
" les Roches-Douvres.
" les Héaux de Bréhat.
" la Croix.
" Creac'h (Island of Ouessant).
" le Four.

* The subject of LIGHTHOUSE ILLUMINATION forms too the theme of an article in the third volume of Johnson's Cyclopedia; by Maj. P. C. Hains, Engineer-Secretary to the Lighthouse Board of the United States.

LIGHT HOUSE FOR SOUTH WEST LEDGE L.I. SOUND

PLATE XVIII
TRANS. AM. SOC. CIV. ENG'R'S.
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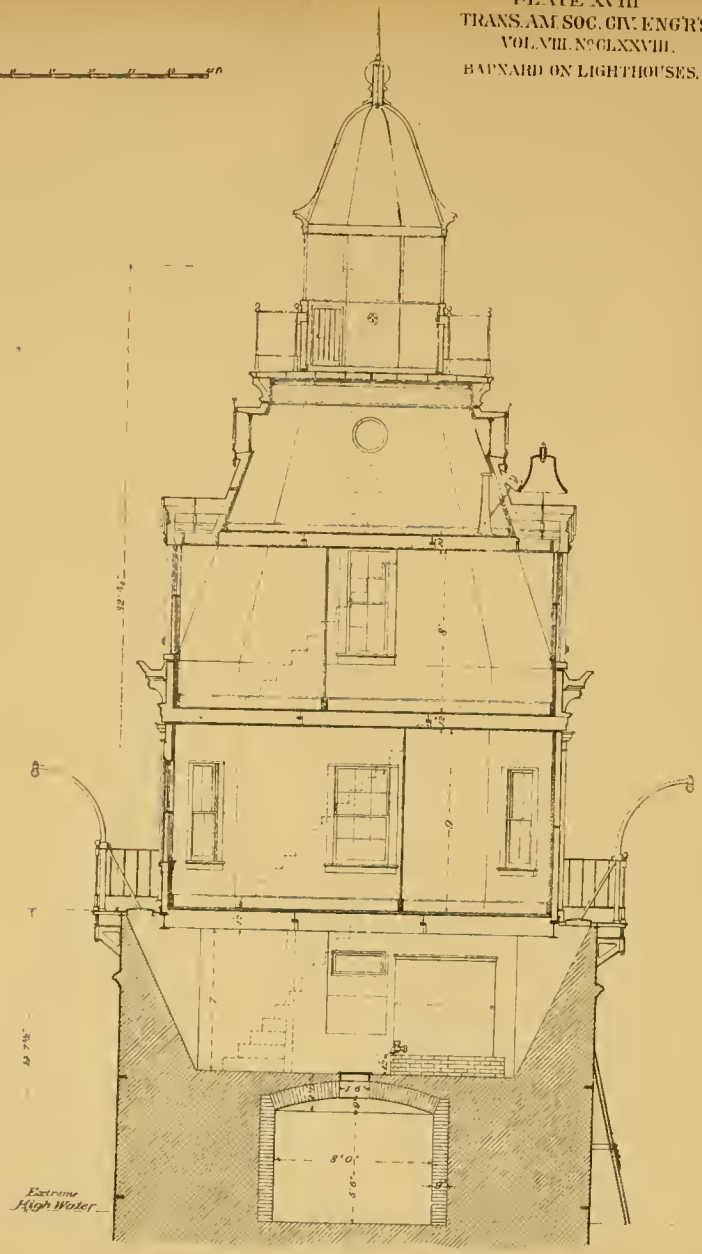
BARNARD ON LIGHTHOUSES.

Scale.

Front Elevation.



Section.

Lighthouse of la Banche.
" les Barges.
" la Palmyre.
" Saint Pierre de Royan.
" Ar-Men.
Turret and candelabrum for port-lights.
Apparatus for lighting.
Lamps and appliances for the use of mineral oil in lighthouses.
Buoys and beacons.

These structures are described in a general way in the report of Lieut. Paul, and I shall only mention three of them, the more especially as drawings cannot be presented, except in one case. Availing myself of the printed "notices of the models, charts and drawings relating to the works of the 'Ponts et Chaussées and the Mines,' which, in English and in French, were furnished to professional visitors to the special exposition of the Ministry of Public Works."

The lighthouse of the Héaux de Bréhat is situated about three miles (five kilos) seaward from the most northerly point of the peninsular of Brittany, France. The character of its site is not described; but the work is reckoned among the "sea-rock lighthouses" of the world, which, besides the Minot's (American), may be thus enumerated: "Eddystone," "Bell Rock," "Skerryvore," "Bishop Rock" (1853), off the Scilly Islands, "The Small's Rocks," entrance to Bristol Channel, "Hanois Rocks" (1862), Island of Alderney, "Barges d'Olonne" (1861), west coast of France, "Wolf's Rock" (1869), off Land's End, England, and "Alguada Reef" (1865), Bay of Bengal, and the "Great" and "Little Basses Light," off the Island of Ceylon.

"The Héaux de Bréhat consists of a cylindrical tower 47 metres 40 inches in height from the arris of the base to the foot of the lantern, and is divided into two principal parts. The lower part is intended to support the strongest pressure, and to resist the most violent shocks of the waves; it is, therefore, constructed with great solidity. With this view the profile of the exterior follows a concave elliptic curve, which gives a large projection to the base; it is 18 metres in height, 13 metres 70 inches diameter at the base, and 8 metres 60 inches at the top, and the masonry is solid up to 1 metre above the highest tides.

"The auxiliary works were established on the Island of Bréhat, about ten kilometres from the rock, in order to take advantage of the

facilities for embarking materials, and of the favorable currents of ebb-tide, which tend directly from the island to the site of the lighthouse. Each course was dressed and accurately fitted together before its embarkation, and was afterwards landed at its destination on the rock, and carried to the tower by a series of cranes which passed the stones from one to another.

"Notwithstanding the violence of the shocks to which the lighthouse of Bréhat is exposed, it was not deemed necessary to have recourse to the means employed in similar cases to ensure the solidarity of all the stones of the edifice; but each course of the basement was divided into a certain number of great key-stones, each of which was fastened to the underlying parts by four granite plugs, let into the two adjacent courses, and placed at the angles of the compartment.

The lighthouse "des Barges" (*Phare des Barges*), is 2,100 metres from the coast, and is situated on the west of les Sables-d'Olonne, on the plateau of the great Barge d'Olonne (about 50 miles N.E. of La Rochelle), which is about 600 metres in length by 300 metres in breadth, and is entirely under water, with the exception of a few points emerging here and there in isolated groups.

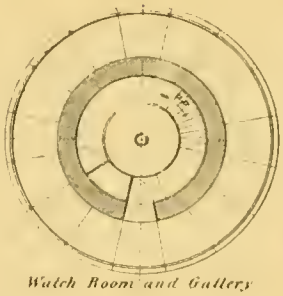
The cylindrical tower is 24.81 metres in height above the rock, not including the turret of 2 metres. It is solid, and has elliptic facings up to 4 metres above the highest tides, or 8.50 metres above the rock, where the hollow part commences. The basement is 12 metres in diameter at the base, and 6.50 metres at the upper part. The hollow part is 16.31 metres in height, and 3.50 metres interior diameter; and the walls are 1.50 metres in thickness at the base, and 0.77 metres at the top, which constitutes a diminution of 0.045 per metre.

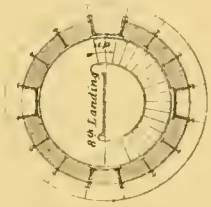
"At the 'Barges' lighthouse the tide currents are not very strong, but the violence of the sea is such that the spray sometimes rises to a height of more than 30 metres, and falls on the cupola. This reason dictated the expediency of so large an extent of basement, also its execution in solid masonry with facings of dressed granite, fastened by tenons and mortises.

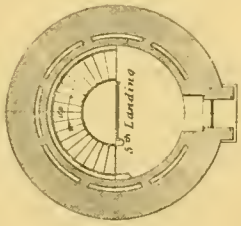
"The entrance door, to which access is gained by a ladder let into the masonry, is placed 4 metres above the highest tides. At this level commences the hollow tower, the walls of which are entirely in roughly dressed granite. It is divided by brick vaults into five stories, connected

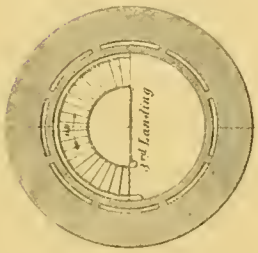
FIRST ORDER
L.H. FOR BODY'S ISLAND, N.C.

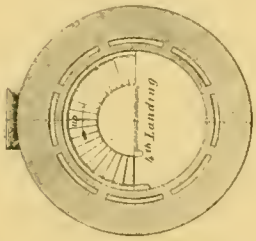
5th District.

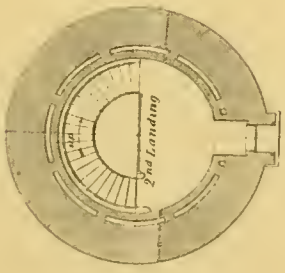


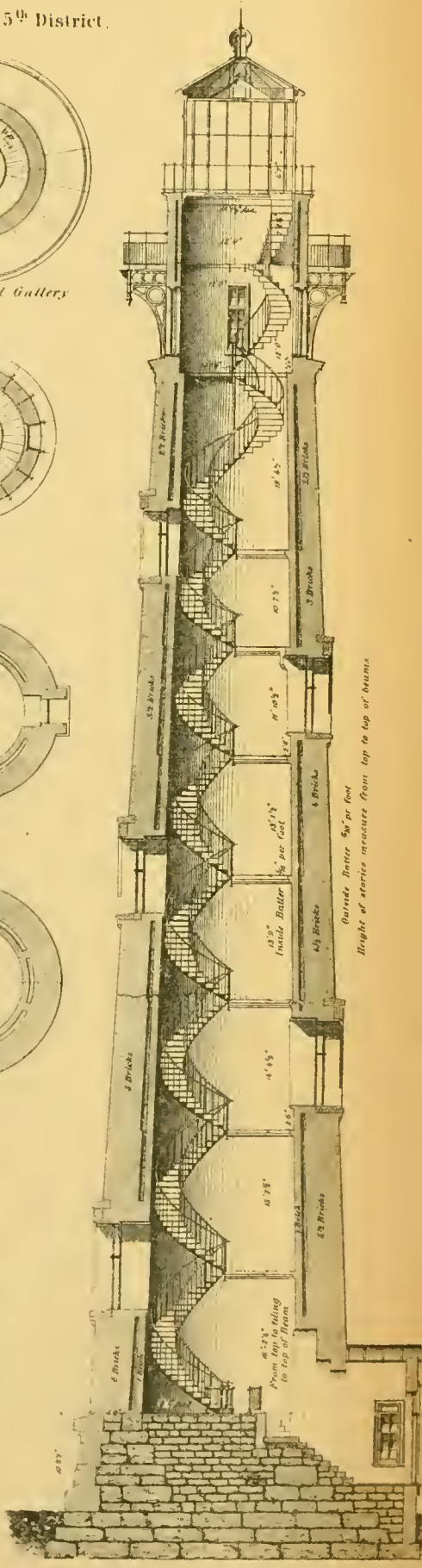












by stairs; in stone for the lower story, and in cast iron for the others. A double cincture in bronze consolidates the tower from the upper vault.

"The foundations presented very great difficulties. It was not found practicable to place the edifice on the point most elevated and most convenient for approach, as in that place the rocks were detached and full of fissures. This circumstance compelled the adoption of a site most exposed to the sea, and of which the average level was only 0.50 metres above the low spring tides, and 0.80 below low neap tides. The irregularities of the surface, and the inclined veins that it presented, led to the first course of the facing being let 0.25 metres to 0.30 metres into the rock, in order to prevent sliding. Two seasons were required to accomplish the levelling—those of 1857 and 1858—at the same time it ought to be mentioned that the rock is of extremely hard granite, so that not more than twelve stonecutters could be employed at once, and that the number of actual working hours was only thirty-eight in 1857, and forty-five in 1858."

"The necessity of protection from the waves was recognized from the commencement of the works, and for this purpose two jetties were constructed, one of which is 75 metres in length and 3 metres in breadth, with the top made flush with the level of high neap tides.

"The stones of the first four courses were landed and set by means of temporary appliances, consisting of a landing crane let into a post fastened to the lighthouse, and a setting crane, moveable on a circular plate fixed in the central stonework."

"In the month of July, 1859, more powerful apparatus was put up, consisting of a safety top and lifting shears, which served to raise the stonework of the basement to the level of high neap tides; but in the month of October following, the whole was carried away by a tempest of extraordinary violence."

* * * * * * * * * *

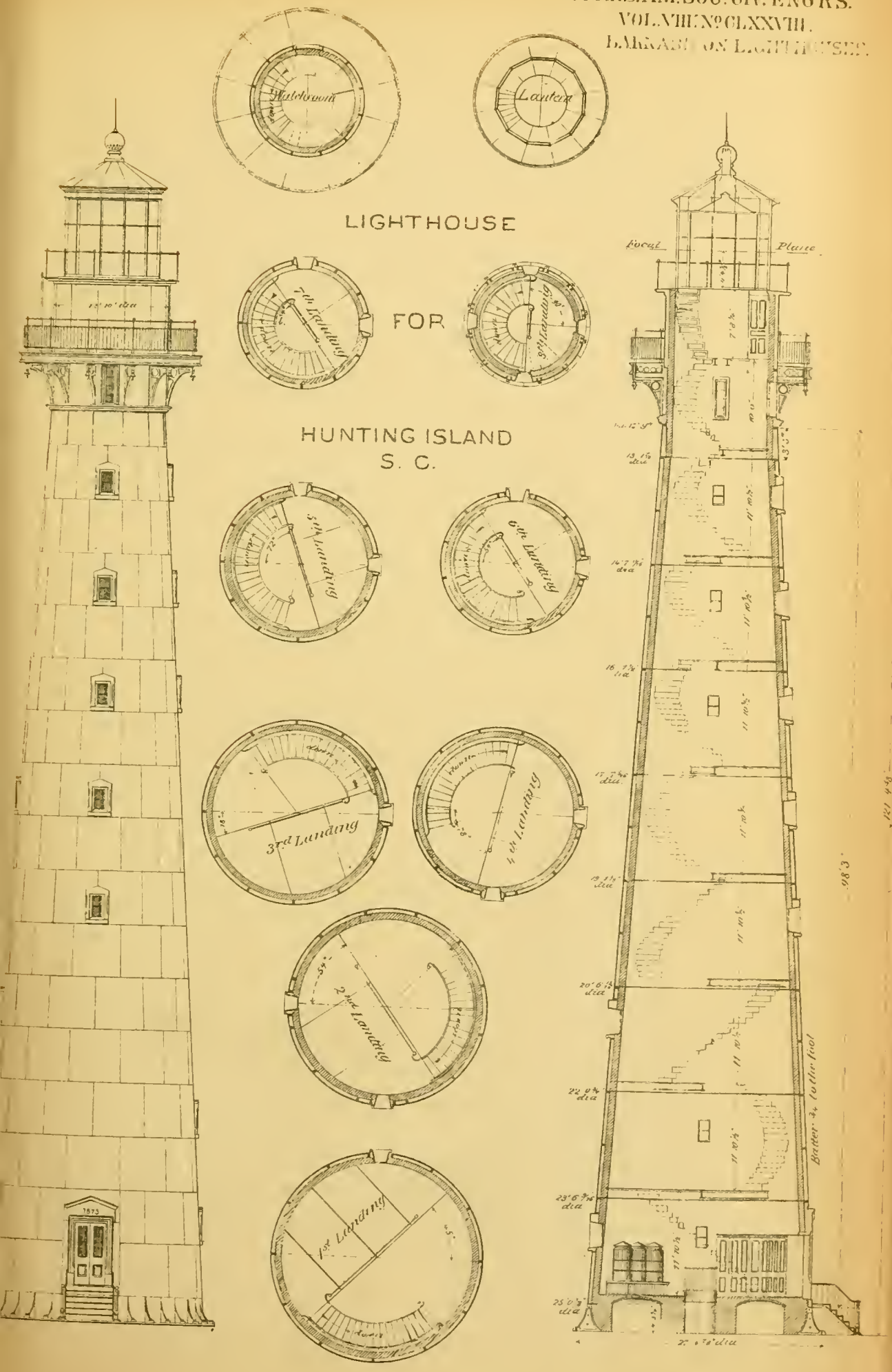
"All the masonry, except one part of the interior of the solid basement, was executed in Portland cement mortar, in the proportion of 1 part sand to 1 of cement for the dressed stones, and 2 of sand to 1 of cement for the rough stones and bricks. The filling in of part of the basement, below the level of the highest tides, was effected with rapidly setting cement mortar from the Isle of Ré, in the proportion of 1 part sand to 1 of cement.

"The works were commenced in 1857, and terminated in 1861. During these five seasons the workmen were able to land 346 times, and in all, to work at the lighthouse 1,960 hours, and at the jetties 308 hours.

"The total cost amounted to 450,000 francs, of which sum nearly 80,000 francs were for accessory works."

A still more interesting engineering construction is that of the "Phare d'Ar-Men." The rock called Ar-Men, but 5 feet above the extreme low tide (which here rises — feet), is a part of a reef (Chaussée de Sein) stretching seaward 8 miles from the Isle of Sein, 20 miles S. of the port of Brest (France). The Chaussée de Sein had long maintained a sad celebrity amongst nautical men. "To anchor a floating light at its extremity had been recognized to be impossible, owing to the great depth of water and to the bottom being thickly studded with rocks. An iron structure was considered impracticable, since the boring of holes (of 0.18 metres or 0.20 metres in diameter) for receiving the posts would be one of the most tedious and difficult operations. Moreover, it was feared, owing to the principal planes of rock-cleavage being vertical, that the structure would not resist the shocks it would be subjected to ; besides, it would be almost impossible to land the cumbrous pieces of the iron framing." The dimensions of the rock were ascertained to be 7 or 8 metres in breadth by 12 to 15 metres in length at the the level of ebb tides ; the surface was very unequal, and divided by profound fissures. The surface descended gradually on the western side, but almost perpendicularly on the eastern. "The following mode of construction was therefore decided upon, viz., to bore holes 30 centimetres in depth and 1 metre apart all over the site, and other holes outside this limit, in order to hold the ring-bolts necessary for craft coming alongside, and to fasten lashings. The object of the first set of holes was to receive wrought iron gudgeons, to fix the masonry to the rock, and to make the construction itself serve to bind the different parts and fissures, and thus consolidated a base the precarious nature of which gave rise to some misgivings. It was proposed that in additon to these gudgeons others should be added, and strong iron chains introduced horizontally into the masonry as it rose, to prevent any possible disjunction.

The services of the fishermen of the Isle of Sein were resorted to for boring the holes. "Two men from each boat landed on the rock, and, provided with their cork belts, lay down upon it, holding on with one


Halfdown
Lantern
LIGHTHOUSE
FOR
HUNTING ISLAND
S. C.
7th Landing
9th Landing
5th Landing
6th Landing
3rd Landing
4th Landing
2nd Landing
1st Landing
Focal Plane
Batter 4 to the foot
1873

hand and using the jumper or hammer with the other ; they worked with feverish activity, the waves constantly breaking over them. * * * At the close of the season seven landings had been effected, and eight hours of work accomplished, during which fifteen holes had been bored in the highest parts of the rock.

* * * * In the following year sixteen landings were effected, eighteen hours of work accomplished, forty new holes bored ; and they even succeeded in partially levelling and preparing the work for the first course of masonry. The construction, properly so called, was undertaken in 1869. The galvanized wrought iron gudgeons, 0.06 metre square and 1 metre in length, were fixed in the holes, and the masonry was commenced with small undressed stone and Parker-Medina cement. In fact, a cement of the most rapidly hardening character was essential, for the work was carried on in the midst of waves breaking over the rock, and which sometimes wrenched from the hand of the workman the stone he was about to lay. * * * * When a landing was practicable, the stones and small bags of cement were landed by hand, and care was taken to dress the surface of the masonry before commencing a new course. At the close of the season of 1869, 25 cubic metres of masonry had been executed, and these were found intact the following year." At the date of the account quoted the masonry was raised 2.60 metres above the highest tides. "The success of the undertaking may therefore be looked upon as assured, and at this stage the work may be expected to advance more rapidly."

From the foregoing, the Phare d'Ar-Men is *sui generis* among sea-rock "lighthouses ;" it is the only one in which, instead of massive blocks dowelled and dovetailed into cohesive continuity, small undressed stones (*petits moellons bruts*) have, through necessity, been made to serve.

Through the kindness of M. Lavoinne, Engineer of Ponts et Chausées and Delegate of the Ministry of Public Works to the Centennial Exhibition, I was furnished with the printed "*Notices sur les Dessins*," &c., there exhibited, and from which the above is taken, with a drawing showing the progress and state of the work up to the close of the year 1875 ; but feeling a great interest in this remarkable work, I am able, through the kindness of the Minister of the United States, the Hon. E. B. Washburne, and the courtesy of the French Ministry of Public Works, to present (Plate XXIII) a drawing showing the yearly progress

of the work to the close of the year, 1876, and the table herewith, which gives a summary of the work yearly executed, with cost, &c.

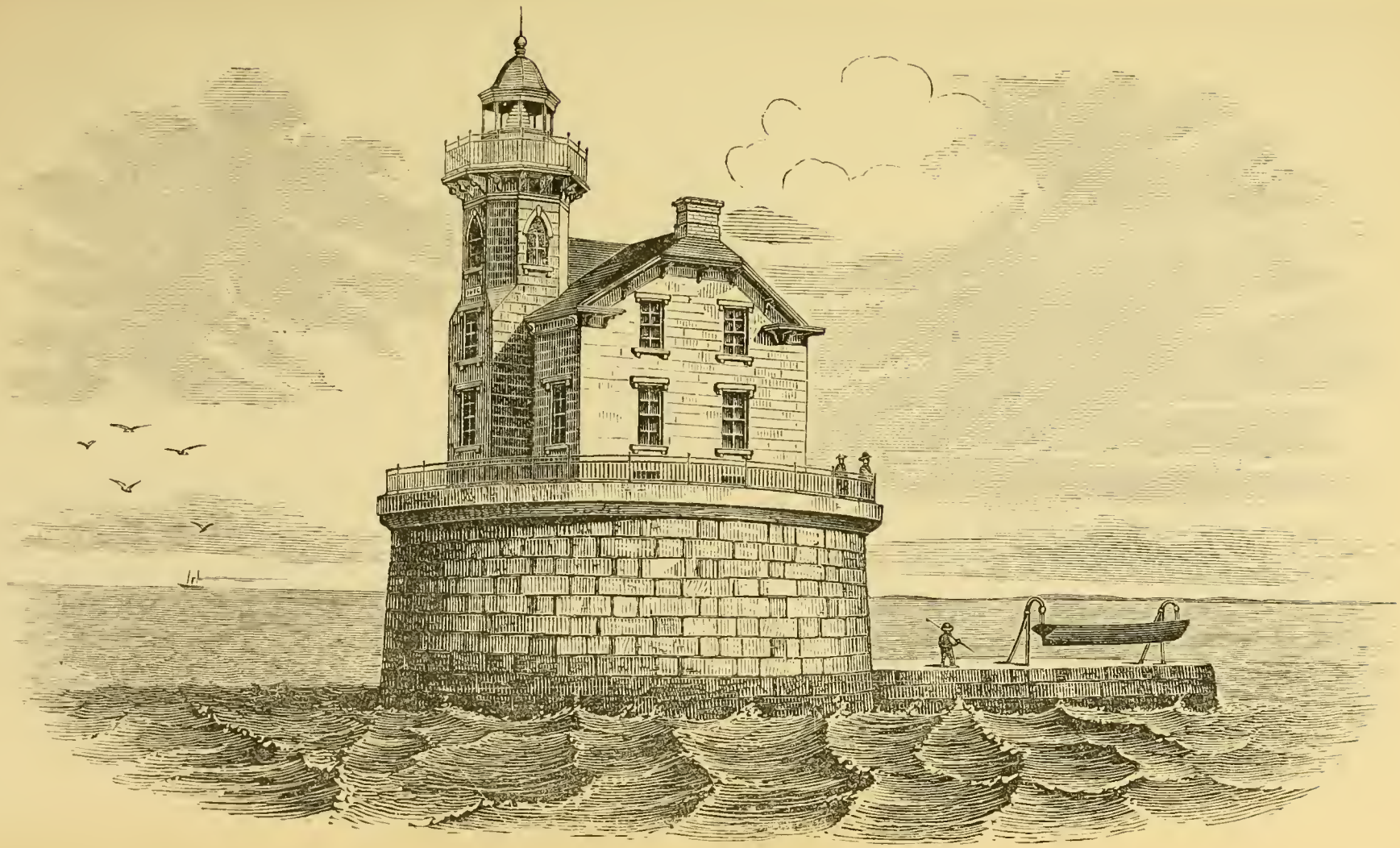
Years.	Number of		Volume of Masonry executed.			Expenditure for the year.	Average Cost of a Cubic Metre.
	Landings.	Hours passed on rock.	Per year.	Per landing.	Per hour.		
						Francs.	Francs.
1867.....	7	8				8,000	
1868.....	16	18				21,000	
		h m.	m. c.	m. c.	m. c.		
1869.....	24	42.10	25.05	1.04	0.60	25,000	998
1870.....	8	18.05	11.55	1.44	0.64	26,336	2,289
1871.....	12	22.10	23.40	1.95	1.05	17 000	721
1872.....	13	34.20	54.55	4.20	1.62	40,000	727
1873.....	6	15.25	22.00	3.67	1.43	62,000	2,818
1874.....	18	60.10	115.30	6.41	1.91	71,800	623
1875.....	23	110.55	203.00	8.80	1.82	76,000	375
1876.....	23	162.45	128.00	5.56	0.78	80,000	625
		h. m.	m. c.	m. c.	m. c.		
Totals or Averages	127	466.0	582.85	4.59	1.25	429,136	733

"In the year 1876 only the month of July proved favorable; having been scarcely so previously, and permitting only 19 hours' work in all August and September. Nevertheless 162¾ hours of work were attained; an amount greater than that of any previous year. The sea, during a greater part of the winter was unusually rough on this coast; but causing not the slightest damage to the masonry."

Although no foreign nation except France represented her light house construction at the Exhibition, yet in an *engineering* point of view we need but a few additions, and those from English models, to make our review of the light house engineering tolerably complete.

The Eddystone, well known to all engineers, was the forerunner of the subsequent sea-rock lighthouses. Its more immediate successors—the Bell Rock and the Skerryvore—are described in works easily accessible to professional engineers. The Wolf Rock (off Land's End), described by Major George H. Elliot ("European Lighthouse Establish-

PLATE XXI.



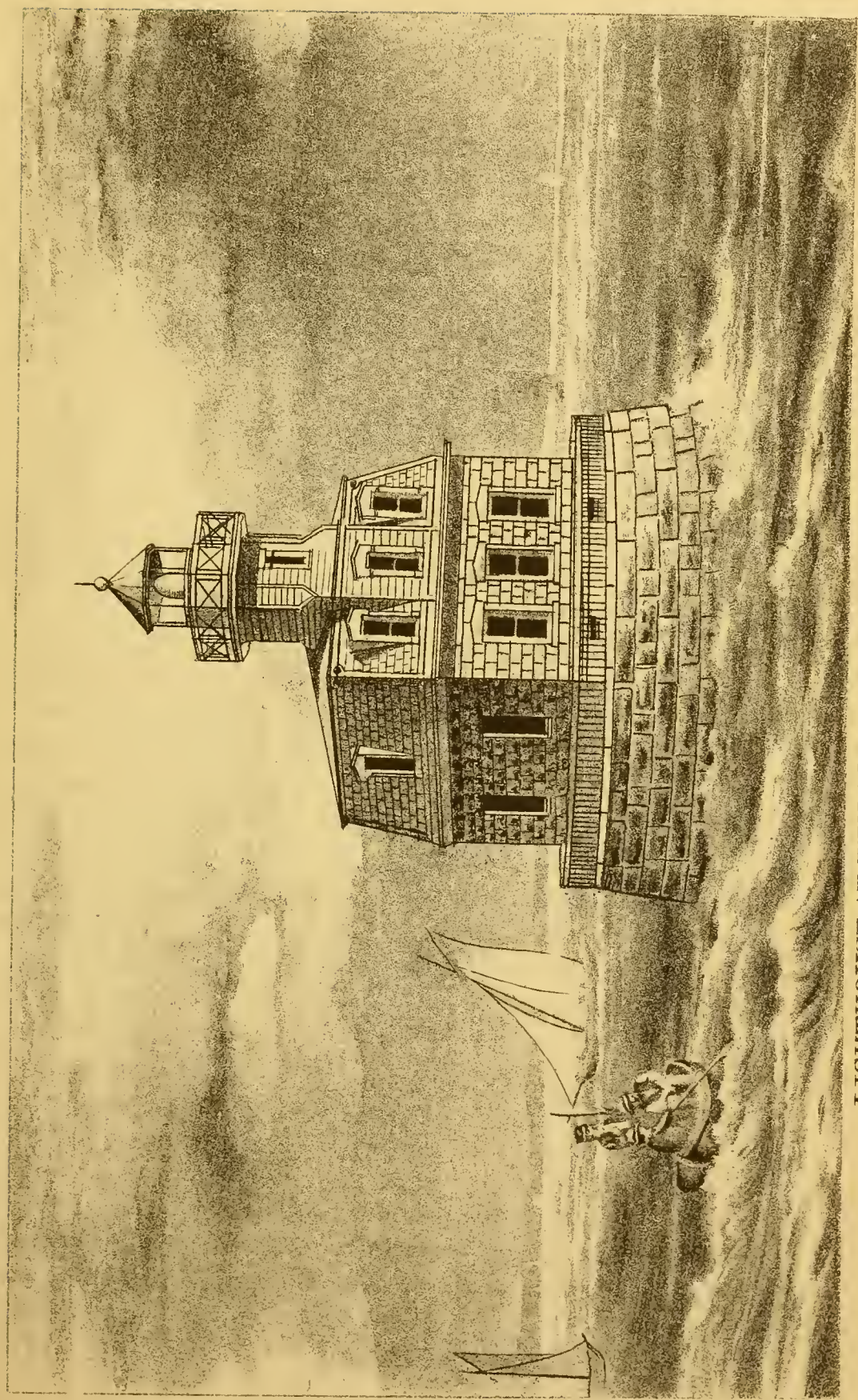
RACE ROCK LIGHTHOUSE.

ments, 1873") as "perhaps the most elaborate and difficult of erection" on the British coast, as likewise the most recent, is on a rock 17 feet above low water, but submerged at high tide (which rises 19 feet), and of which the area scarcely exceeds the base of the tower; while the immediately surrounding depths reach 20 fathoms. The tower is 41 feet 8 inches diameter at base, 116 feet high, and solid from base to a height of 39 feet, or to the door of the lighthouse. The thickness of the walls at the doorway is 7 feet 9½ inches, and at the top, which is 17 feet in diameter, it is 2 feet. The shaft is a concave eliptical frustum, the generating curve of which has a major axis of 236 feet and a minor axis of 40 feet. "The stones are laid in off-sets to the level of 40 feet above the rock, with a view of breaking the sea, and above that height the surface is smoothly cut. Each face-stone is dovetailed vertically and horizontally into the adjoining stones, and each stone is bolted to the course below it by two 2-inch bolts—of yellow metal for the exterior and galvanized steel for the interior stones. The dovetailing was adopted not only for increase of strength, but to prevent displacement by the sea during construction, before the superincumbent weight of the additional courses could be obtained, and to protect the cement mortar of the joints from being washed out before it could be set."

The Bishop Rock Lighthouse, the construction of which preceded Wolf Rock, and which, like the Minot's, succeeded a storm-destroyed (though incompleted) iron pile structure, is mentioned by Findlay (*Lighthouses of the World*) as "probably the most exposed lighthouse in the world." The force of the waves is supposd to surpass even the measure registered at Skerrymore, *i. e.*, 6 000 pounds per square foot. "On January 30, 1860, a storm-wave shook this tower, and tore away the bell, weighing 3 hundredweight, from its support at the top of the tower, more than 100 feet above the sea. * * * Therefore, if these sea-beaten towers were not at least equal in weight to a solid block of granite of 60 or more feet in height, they would not be able to withstand the waves." In its construction it resembles very closely the Wolf Rock. From its tower beamed upon the fog-beshrouded steamer "Schiller," already upon the fatal rocks, the too late warning.

Two recent engineering structures of the same kind deserve the attention of engineers. A brief description of them will conclude my very general review of lighthouse engineering as directly or indirectly presented to us at the Centennial Exhibition.

On the Great and Little Bassas (or Bosses) Rocks, lying off the S. E. coast of Ceylon, in the direct path of vessels plying between the Suez Canal and ports of India, China, Japan, &c,, the Trinity House Corporation has constructed two lighthouses. The former (December, 1876) is completed and the latter nearly so. "The Great Bassas rock is about 6 feet above mean water-level, and the Little Bassas is only awash at low water, and is seven miles from the shore. These reefs, which are composed of hard red sandstone, are exposed to the full fury of the sea during the N. E. and S. W. monsoons, so that the days available for working are few, and these are almost exclusively during the prevalence of the N. E. monsoon, which commences in November and terminates in April ; and even of this short period only half of it can be relied upon as safe for working. The towers are built of Scotch granite, the blocks of which were fitted together in the quarries before shipment. The blocks forming the walls and floors of both lighthouses are dovetailed together, both vertically and horizontally, upon the system adopted by Mr. Douglass in the Wolf Rock and Hanois Lighthouses." To land the stone "a strong mast 45 feet high, and supported by chain-guys, was shipped into the rock in a vertical position, and from this was supported a derrick which could be swung over towards the tower by means of a chain and a crab. The steamer was moored at a distance of 180 feet from and parallel to the rock, and the blocks of granite contained in the hold were ranged on two tiers of rollers, so as to facilitate their being brought under the hatchway, where an iron lifting, working in guides. conveyed them to the level of the deck." One barrel of the forward winch lifted the stone to the deck and deposited it on rollers in readiness to go out of the gangway. To one barrel of the after winch was attached the end of a half-inch chain, which passed first through a leading block at the gangway, then through another at the foot of the derrick, through a pulley at its top, and from thence through a block attached to the stone, and back to the head of the derrick, where it was made fast. For easing off the stone and to keep it in check, there was attached to it a second chain, the further end of which was coiled on the second barrel of the forward winch, which was controlled by a powerful brake. In landing a stone the aft steam winch was started, and, as the stone went over the side, the controlling chain was eased away by the brake until the stone entered the water, when it was gradually "paid" away as the after winch worked the stone ashore. The stone on reaching



LIGHTHOUSE AT PENFIELD REEF, LONG ISLAND SOUND.

the shore was swung by the derrick towards the tower, and lowered into its place. When the building rose to a height too great for the derrick to work, a steam winch was fixed upon the rock for hoisting the granite blocks to the top of the tower.

"By the very ingenious contrivance by which the stones were conveyed from the ship to the rock below the surface of the water they were out of the influence of the wind, and at the same time more than two-fifths of their weight was taken off, due to the difference between the specific gravities of granite and water. As these two lighthouses are but 20 miles apart, and very similarly situated, it was of the utmost importance to prevent the one being mistaken for the other either by day or night. Hence, a difference in the forms of the heads of the two towers, and also a difference in their lights. The Great Bassas light is distinguished at night by giving red flashes at intervals of 45 seconds, the duration of each flash being about 7 seconds, and that of the eclipses about 38 seconds." The illuminating apparatus of the Little Bassas Lighthouse is of a novel character, being upon the very beautiful "group-flashing" system of Dr. Hopkinson, whereby flashes in groups of two or more are given in quick succession, instead of single flashes at stated intervals of time.

A more detailed account of these important works will be found in "Engineering," October 27, 1876.

It should be stated that through the courtesy of the proprietors of Johnson's Cyclopedia, I have been permitted to transcribe from my own previously prepared article, "Lighthouse Construction," accounts of many of the works herein mentioned, and have been thus spared a double labor.

The following authorities may be consulted :

A Narrative of the Eddystone Lighthouse, &c., &c., by John Smeaton, London, 1797.

An Account of the Bell Rock Lighthouse, &c., &c., by Robert Stephenson, Ed. 1824, with a historical view of institution and progress of the Northern (or Scottish) lighthouses.

Account of the Skerryvore Lighthouse, with Notes on the Illumination of Lighthouses, by Alan Stephenson, London, 1848.

Article "Lighthouse," by Alan Stephenson, Encyc. Brittanica ; Articles "Lighthouse Construction" and "Lighthouse Illumination," Johnson's New Universal Cyclopedia ; "Report of the Officers consti-

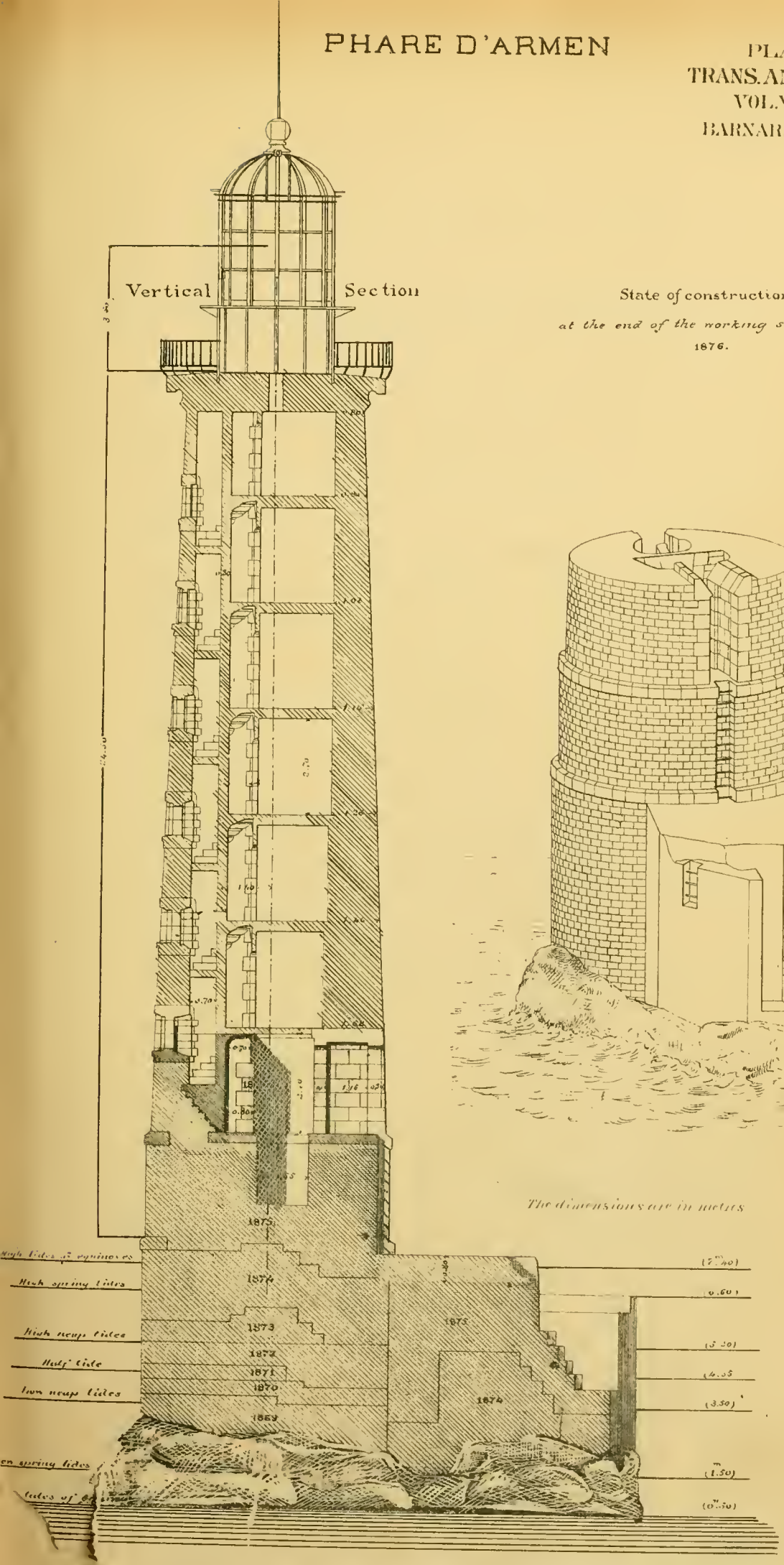
tuting the Lighthouse Board," &c., 1852 (Ex. Doc., Senate, No. 28, $\frac{32}{1}$); "Documents relating to Lighthouses, 1789 to 1871," by the U. S, Lighthouse Establishment, Washington, 1871; Extracts from "British Lighthouse Reports," by do. do., Washington, 1871; "European Lighthouse Systems," by Major Geo. H. Elliot (Ex. Doc., Senate, No. 54, $\frac{43}{1}$); "Memoir upon the Illumination and Beaconage of the Coasts of France," translated from the French of M. Reynaud, Director, &c., by Colonel P. C. Hains, Engineer Secretary U. S. Lighthouse Board;" and list of authorities at end of article "Lighthouse," Encyc. Brittanica.

The Illustrations which follow are :—

Plate No.	XII.	Minot's Ledge Lighthouse, with Comparative Sections of other Sea Rock Lighthouses.
do.	XIII.	Spectacle Reef Lighthouse.
do.	XIV.	Brandywine Shoal do.
do.	XV.	Fowey Rocks do.
do.	XVI.	Ship Shoal do.
do.	XVII.	Southwest Pass do.
do.	XVIII.	Southwest Ledge do.
do.	XIX,	Body Island do.
do.	XX.	Hunting Island do.
do.	XXI.	Race Rock do.
do.	XXII.	Penfield Reef do.
do.	XXIII.	Phare d'Ar-Men.

PHARE D'ARMEN

PLATE XXIII
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VIII. No. CLXXVIII.
BARNARD ON LIGHTHOUSES.



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CLXXIX.

(Vol. VIII.—April, 1879.)

MINOT'S LEDGE LIGHTHOUSE.

A BRIEF MEMOIR BY THE LATE LIEUT. COL. B. S. ALEXANDER, BREV. BRIG. GEN., U. S. A.

Presented and read April 2d, 1879, by J. G. BARNARD, U. S. Army, Hon. Member of the Society.

PREFATORY REMARKS BY J. G. BARNARD.

On the completion of the work, there remained the sum of $30,000 of the original appropriation unexpended. It was the intention of the Lighthouse Board to devote this unexpended balance to the preparation of a complete history, with plans and pictorial illustrations. But the constructing engineer, the late Gen. B. S. Alexander, relieved from the work only a few weeks before the breaking out of the war, was called upon for services in arduous and absorbing labors during the whole period of its duration.

Hence he was prevented, while the history of the work was yet fresh in his mind, from undertaking it. Soon after the war he was ordered to the Pacific Coast, where he remained in active discharge of his duties until his death. Unaddicted to writing or sedentary work of any kind, and separated from the documentary collections of the lighthouse establishment, he was never properly situated for the execution of a work to which, besides, he was little inclined.

The following brief memoir was prepared four years ago for, and at the earnest solicitation of, the writer. It is believed to be the only connected memoir, by its author, on the subject.

GENERAL ALEXANDER'S MEMOIR.

The iron lighthouse was carried away in the spring of 1851.*

The present Lighthouse Board was organized in 1852. It was immediately determined by that board to replace the former structure, if possible, by a stone tower.

A careful survey of the rock was made by Major Ogden, of the Corps of Engineers, acting under orders of the Board.

This survey was what may be called a topographical survey, with horizontal curves only three inches apart. In other words, the survey showed a plan of the rock at low water, with the curves where horizontal planes passed three inches from each other vertically, both above and below that level, would intersect the rock, all these curves being projected on the plan.

The survey showed that the top of the highest point of the rock was 3′ 6″ above the plane of low water, It also showed that it would not be possible to obtain a tower of a greater diameter than 22′ without going outside the line of low water. This diameter was not considered sufficient either for stability or accommodation. But it was also shown that by going outside of and below the line of low water, in five places, it might be possible to obtain a tower of 30′ diameter.

The survey was placed in the hands of Gen. Totten, then Chief Engineer of the United States Army and member of the Lighthouse Board, who took upon himself the duty of planning a masonry tower for this

* Reference is here made to the iron skeleton tower designed and erected (1845–48) by Capt. W. H. Swift, U. S. Topographical Engineers, destroyed by the great storm of April 14–17, 1851. An account of this structure, as also of the circumstances of its destruction, will be found in Johnson's Cyclopædia, article, *Lighthouse Construction* (J. G. B.).

difficult position. With the exception of the lower stones of the foundation, which had to be studied out on the rock itself, and some details of construction, the tower was built, throughout, according to the plan of Gen. Totten.*

In April, 1855, Lieut. Alexander, of the Corps of Engineers, U. S. A., was assigned to the duty of constructing the lighthouse. He furnishes the following notes descriptive of the method of overcoming some of the difficulties in the construction of the work.

I first visited the vicinity of Minot's Ledge on the 1st of May, 1855. The weather was fine, and I hoped to land on the rock the next day. But on the following morning, I found an "old swell" running which prevented any boat from approaching the rock. This "old sea" or "old swell" continued with variable weather until Saturday, the 12th of May, when I succeeded in landing on the ledge for the first time. The stumps of the broken iron piles of the old lighthouse first attracted my attention. They had a melancholy appearance; they told of disaster, and the determination to remove them was involuntary. The wreck of the old lighthouse was visible under water, as we stood on the rock, and I determined to remove it also. (For the appearance of these remains, see the Fig. 3, article already cited, Johnson's Cyclopœdia.—J. G. B.)

It was difficult to stand on the rock. It was covered with mussels and seaweed, but otherwise was much as I expected to find it. I examined it carefully, and measured it at dead low water in hopes to be able to report that we might get a few inches more than thirty feet diameter for the foundation; but I was disappointed in this hope. After waiting about an hour, the rising tide drove us off, but I visited the rock again on the following day, and with the same feelings as before.

How was it possible to cut down this rock into any shape suitable to receive the foundation stones of the tower? Could it be done?

We could not land, even in the summer season, at times for weeks together; and when we could effect a landing, a part of the ledge was at all times under water, and the remainder only bare for one or two hours at low water of spring tides. The space was contracted, and the sea broke with such violence during easterly weather that no coffer dam was possible. How were we to begin? What should be the process? Where

* The "Annual of the National Academy of Sciences," 1866, gives a full account of the connection of the late Gen. Totten with this work. J. G. B.

were the workmen to live, and what were they to do while waiting for an opportunity to land on the ledge ?

The ten or twelve days I had spent on shore, or on the buoy tender, while waiting to effect a landing, enabled me to reflect seriously on these subjects, and, in fact, to solve these problems.

I could foresee that cutting the rock into shape to receive the foundation stones would prove to be a very tedious, troublesome and expensive operation, and one requiring incessant vigilance. I knew, if we hoped to establish this foundation in any reasonable time, that when we were enabled to land we must do so with a large party of skilled workmen, with all the necessary tools and implements.

To have engaged such a party of workmen and placed them on board vessels near the rock, or on the shore in sight of it, with instructions to take advantage of every opportunity to work on the foundation pit, would have been an easy operation, but it would not have been good engineering.

The men would have been idle nine-tenths of the time. They could not have been kept properly disciplined ; when wanted they would not have been at their posts, and even if they had been they could not have worked like men who are used to daily labor. Their hands would soon have become soft, and they would shortly have become physically disqualified for such hard labor and exposure as I had before them.

I determined, therefore, to combine the operation of cutting down the rock for the foundation with the cutting of the stone for the tower, and have them both done by the same party of workmen, to whom I could give constant employment and full wages. To accomplish this it was necessary to have a *shore establishment* ; that is to say, an establishment on the shore, as near the lighthouse as posssible, with wharf accommodations, storerooms, workshops, and a stone-yard where the stone could be cut and fitted together preparatory to being removed to the tower.

By providing the necessary vessels and boats, a gang of stonecutters could then work on the ledge when sea, weather and tide would permit, and when they would not, there would be full employment for these men on shore, cutting the stone for the tower.

I determined also to erect a permanent scaffold on the ledge, not a beacon-house, but a structure of iron to which the workmen could be

secured, to protect them from being washed fron the rock, and afford means of temporary security in case of accident to the boats or vessels. This scaffold I also conceived would answer the purpose of a derrick for laying the lower courses of masonry in the tower, and the lighthouse being built around the piles of this scaffold, they would be so many huge bolts to secure it to the foundation of the rock.

All these ideas were embodied in my first report to the Lighthouse Board, dated May 31st, 1855. They were approved, and I immediately set about carrying them into execution.

On the twentieth of June I employed a few men to loosen the wedges around the stumps of the old iron piles and remove the mussels from the top of the ledge. This work was accomplished in a few days.

Having supplied a few tools, and selected Mr. Charles Pratt, of Cohasset, as Superintendent of the work, on account of his great experience in masonry constructions, our small party landed on the rock at daylight on Sunday morning, the 1st day of July, 1855.

The morning was beautiful, clear and calm ; just as the sun was rising above the horizon I took a hammer and chisel, called the party together, and, after a few remarks to them, commenced cutting a bench-level on the highest point of the rock. This bench-level was the point from which all levels were to be taken while cutting down the foundation.

As the whole of the top of the rock down to a plane 1 foot 9 inches below this bench-level, was to be removed, we began on this day and continued for several days to mark points of intersection of this plane with the surface of the rock, cutting thereby level space around the rock upon which the workmen could stand and upon which tools could be placed in comparative safety.

Knowing that the upper portion of the rock, inside of this level space, could easily be cut away long before the foundation on the lower levels could be got ready, no more of it was removed during this season than was absolutely necessary.

Points of the lower levels, defining the portion of the rock that was to be cut away, were also marked whenever the tide would permit. This could be done as well by a small party of men as by a large one ; and as it was evident we could not do much work on the rock during the first season without disregarding all economical considerations, I only

employed a small force and confined our labors, in a great measure, to laying out the work for a larger party for the the next year, and in this way we all acquired valuable experience.

In the year 1855 we worked on the rock 130 hours.

1856.

We first landed on the rock this season on the 1st of April.

One of the greatest difficulties in preparing the foundation was in cutting the vertical surfaces of the rock so as to receive the vertical joints of the foundation stones. The level surfaces could be more easily prepared, because the rock could be plugged off and the surface brought to a plane, even when there was a depth of two or three feet of water over the space to be cut,

There were to be two partial courses of stone in the foundation before the first full course of masonry. The form of every stone in this foundation had been carefully worked out by Gen. Totten; but owing to blind seams in the rock, and to an accident, to be mentioned hereafter, the number and sizes of the stones had to be altered. As finally finished, there are seven stones in the lowest or partial course, all having the levels of their bottom beds below low water, the levels of these bottom beds varying in depth from seven inches to two feet two inches below low water level, the last depth being the level of the bottom bed of the lowest stone in the structure. There are twenty-nine stones in the second partial course; of these, twelve stones have their beds below low water, varying in depth from four inches to one foot two inches below low water.

The following is an outline of the manner of cutting the vertical surfaces around the outside of the tower, and along the inside lines to which the rock was shaped to receive the stones of the lowest courses fitting into it.

The men were provided with 1¼ inch drills, from 2 to 4-feet long, and having marked the ends of a line upon which a vertical surface was to be cut, they would start, at low water, as many holes as possible, about one inch apart, carrying these holes down, at first, to the depth of only one or two inches. During a good tide, three men, one to hold the drill, and two to strike, would start from 20 to 30 holes.

When a line was thus marked these holes became guides, into which

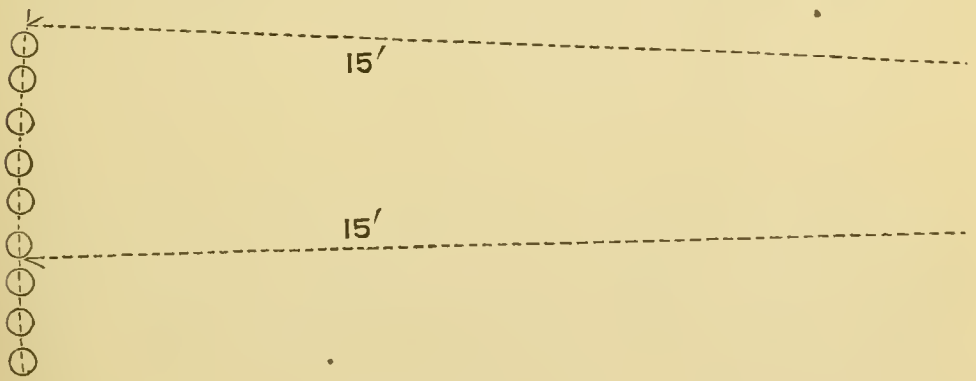
longer drills of the same size could be inserted without danger of making mistakes, even when there was two or three feet of water on the rock. These holes were then drilled down to the exact depth required.

The spaces between these holes were then "set out," that is to say, the stone between the holes was crushed out by a "set," like that used by stone cutters in "setting out" Lewis holes.

This set was nothing more than a piece of octagonal steel, like an ordinary drill, but made so as to be about seven-eighths of an inch by one and one-half inches on the bottom, so as to cover the space between two adjacent holes. Having placed this tool in its proper place, it being too large to enter the holes made by the drills, it was driven to the bottom of the holes with the ordinary striking hammer.

These holes and this setting-out process, having been carried to the required depth all the way around any particular portion of the ledge to be removed, disconnected that portion from the rock to which it had been joined. It was then easily removed, without danger of injuring the adjacent parts.

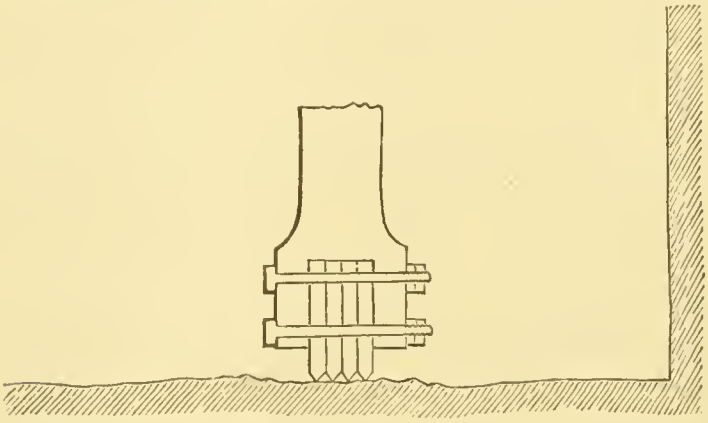
This drilling and setting-out process was carried along all the interior lines of vertical cutting, as well as around the outside or circumference of the foundation pit; the centre of the holes, in the latter case, being placed, as nearly as possible, on the circumference of the base of the tower, or fifteen feet from its centre. Thus:



So that when the circle was set out and trimmed up, the foundation pit was about one-half an inch larger, all around, than the first complete course of stone in the tower; or, in other words, the radius of the foundation pit was fifteen feet and one-half an inch.

The vertical surfaces were "trimmed up," or brought nearly to a plane surface, by chisels and hammers, after the rock, on the side where it was required to be removed, had been knocked out of the way; and the different levels of the foundations, where they were exposed at low water, were hammered in the same way.

But where the stone was *always* covered at low water the stone was first drilled or knocked or plugged off until it was brought down *nearly* to the required level, and then a tool, of which the following is a representation, was used to take the place of the ordinary hammer or chisel:



With tools like this we were enabled to hammer down the surfaces of the lower levels of the foundation pit, even when there were two or three feet of water over the spaces to be hammered.

It has been stated that a permanent coffer dam around this work was out of the question, but I found temporary coffer dams around small portions of the rock of great use, both in finishing up the foundation pit and in laying the lower stones of the structure. These coffer dams were made with sandbags like those we use in building a sandbag battery. The duck was heavy, and, therefore, practically water-tight; the bags being filled about half full of sand. They were, therefore, easily handled. Two or three hundred of these bags built up, at low water, around a small portion of the foundation pit which it was desired to finish, or where we wanted to lay a stone in mortar, would keep out the water for fully half an hour, if the sea was very smooth. The water in the little pit, where we wanted to work, was then bailed out, and by means of large sponges it was kept nearly dry.

These little dams only required a few moments in construction, and, as they were easily removed, they were inexpensive. They answered an admirable purpose in enabling us to see that the work was correctly done; see that the foundation was properly completed; see that the wooden patterns for the lower stones were correct; and then have the satisfaction of seeing the lower stones laid in a bed of mortar, properly spread on its foundation.

Nearly all the stones were thus laid; a few required another device.

Iron Scaffold.

During the month of June, 1856, an iron scaffold was erected on the rock.

It consisted of nine wrought iron shafts inserted into the holes of the iron lighthouse and rising to a height of twenty feet above low water; the whole bound together at the top by a strong wrought iron frame.

The posts were ten inches in diameter at the rock, and seven inches in diameter at the level of the frame.

This scaffold gave us some command of the rock, and it gave great confidence to the new hands. By stretching lines between the posts across the rock in different directions, about two or three feet above it, every workman had something within his reach to lay hold of when a wave would break over the rock, thus doing away with the constant apprehension of danger.

In 1856 we worked on the rock 157 hours.

1857.

On the 19th of January of this year, the bark "New Empire," loaded with cotton, was thrown against our scaffold during a violent northeast gale, and swept it from the rock, breaking off the iron posts very much as those of the iron lighthouse had broken when it was carried away, and shattering the top of the rock, in some places, so that a portion of our labor during the preceding year had to be done over again.

This was a very unfavorable season for work ; the whole working time on the ledge being only 130 hours. Nevertheless, the foundation-pit was nearly completed, and four stones of the foundation were laid.

1858

was a much more favorable season. The foundation pit was finished this year, and the masonry of the tower was carried up to the 6th course (inclusive).

The mortar used throughout the structure was the best quality of pure Portland cement. No lime or sand was used.

The lowest stone was laid July 11, 1858. This stone, and some six others, had to be laid in the water.

The method adopted for securing a bed of mortar under these stones, and also on their vertical joints, was as follows: A large piece of thin muslin was spread on a platform on the ledge. A layer of mortar was then spread over it of the required thickness. The stone was then laid on this bed of mortar. The vertical joints of the stone were then plastered with mortar. The cloth was folded up and laid smooth along these vertical joints, cutting away its superfluous parts. After remaining five or ten minutes the mortar would begin to set so that it and the attached cloth would adhere to the stone. The stone was then laid in this envelope, which protected the mortar from the dissolving action of the water while it was being lowered into position. I had previously made some experiments at our wharf by cementing stones together in this way under water, and they satisfied me that the mortar would ooze through the threads of the cloth so as to form a good bond to the stone below.

All the lower courses of stone in the tower were laid from an iron mast, which was set up in the centre hole of the former lighthouse. The machinery and rigging, which completed the derrick, had to be put on and taken off this mast every day that we landed for the purpose of laying masonry. It was of simple construction, and arranged so as to float in the water, so that all we had to do in "stripping the derrick," after our tide's work was over, was to cast the machinery loose from the mast and throw it, with the attached rigging, overboard. It could then be towed to the tender.

We worked on the rock this year 208 hours.

1859.

The masonry of the tower was carried up this year to the top of the 32d course, being 62 feet above low water.

Working time on the tower this year 377 hours.

1860.

The lighthouse was completed this year. The last stone was laid on the 29th day of June, which was just five years, lacking one day, from the time the workmen landed on the ledge.

No life was lost in building this lighthouse, nor was any person seriously injured.

The following were the principal regulations for the safety of the workmen while cutting down the ledge and laying the masonry of the foundation :

1st. No person should be employed on the work who could not swim, or who could not pull an oar and manage a small boat.

2d. No landing on the rock should ever be attempted from one boat. There must always be, at least, two boats.

3d. While the workmen were on the ledge, a small boat with at least three men in it should be stationed immediately alongside the rock, on its lee side, to pick up the men who were occasionally washed from the rock.

Beginning at the third, or first full, course of stone, all the stones in the lighthouse were fitted together at our shore establishment ; each stone occupying the exact position it was afterwards to take in the tower.

We would build up eight courses of stone on a platform, then take down top or eighth course and fit it together again on another platform, which then became the foundation upon which the 9th, 10th, 11th, and subsequent courses were fitted.

The stones on the first platform being marked and laid away in the stone yard in the order in which they would be wanted at the tower.

The foundation stones were secured to the ledge by galvanized wrought-iron bolts, inserted through these stones and into the ledge to the depth of one foot.

The stones of the solid portion of the lighthouse were secured to the courses below by similar bolts entering seven inches into the lower course.

After the destruction of the scaffold which had been erected on the ledge, a new one was prepared similar to the first, but it was never erected as a scaffold. The eight outer posts, however, were inserted in the eight outer holes of the former lighthouse, after the masonry of the tower had been carried up to the 10th course, the spaces around these posts being filled with a grout of Portland cement. They are supposed

to give additional strength to the tower, holding it more securely to its rock foundation.

The light was exhibited for the first time at sunset, November 15, 1860.

The cost of the lighthouse, and of the keeper's houses on shore, was $300,000.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CLXXX.

(Vol. VIII.—May, 1879.)

THE CONSTRUCTION AND MAINTENANCE OF ROADS.

By EDWARD P. NORTH, C. E., Member of the Society.

Read April 16th, 1879.

The writer wishes to give the Society some statistics and suggestions regarding the construction and maintenance of wheelways, partly drawn from his experience in charge of such work and from observation and information acquired in this country, and recently in London and Paris.

EARTH ROADS.

In the construction of an earth or gravel road the effort should be to keep the material near the surface as nearly homogeneous as possible, that the surface may be uniformly hard. The upper layers at least should be thoroughly rolled in thin layers, with sprinkling, if the material is too dry to pack well. The most efficacious roller for this purpose is of two sets of disks, one about 8 inches less in diameter than the other, placed alternately on the axis of the roller. It is understood that the cost of compacting reservoir embankments with this roller is about three-fourths of a cent per cubic yard. The writer has never seen it used in road maintenance.

When the soil is sandy but little can be done besides covering it with some more tenacious material. Clay, or clay hard-pan, is the best, unless a sufficient coat of gravel can be afforded. Even a clay road, if the

traffic is not too heavy, can be kept in a firm state by careful and continuous maintenance; a coat of sand or hard-pan is, of course, desirable.

The plan often pursued of repairing roads once or twice a year is not economical, for the dilapidations increase in a heavy ratio after they commence.

A fair average for re-forming a mile of old road 30 feet wide between gutters, where the material was mostly cast from the sides, was 164 days, 10 hours each, of laborers, and two days of a double team hauling earth, carrying away stones, and moving tool-box. The use of a railroad scraper would have been an economy.

Maintenance is most economically performed by double teams, with hones or scrapers, rollers, and the watering cart in dry weather. The hone or scraper is often an oak plank, 2 inches thick, 10 inches broad, and 9 or 10 feet long, shod on its lower edge with a ¼-inch plate of iron. Drawn vertically along the road either by a tongue or a chain—in the first case it has two handles like plow-handles—in the second it has a vertical handle, and the earth is dumped by pushing it forward; a piece of plank, about 3 feet long, being fastened behind, by riding on which the driver can regulate the amount of earth moved. These are drawn over the road, inclined 7 or 10 degrees from a perpendicular, to the line of travel. So that, besides filling small depressions, they, to a slight extent, scrape the earth to or from the centre of the road. There are also some patented machines, combining a scraper and roller in a frame, which are said to be very effective. 46 000 to 47 000 square yards can be covered in a day, while not more than 2 300 can be put in order if the road is rutted and gullied. While hones are of little use on muddy roads, they are effective just as it is drying.

The ordinary type of roller has 6 rings, the whole length being 6 feet, and weighing about 2 tons; with frames that, will hold 1½ tons of stone. A better is of 2 rings, 3 feet long, also weighing 2 tons. Another is figured in Clemens Herschel's Prize Essay on Roads, and in General Gilmore's Roads, Streets and Pavements.

The roller should follow the re-forming of the road-bed, whether with hones, shovels, or the ordinary railroad scraper.

The writer has rolled earth roads with a 15 ton steam roller, but not enough to be certain as to its economic value; where the soil contained a fair amount of clay, the road-bed was left very hard, and wore well.

A water cart holding 60 cubic feet will water 830 to 860 square yards, and can be drawn by an ordinary team over any road that is worth

watering. Two sprinklings per day will keep the road in good condition, though not free from dust in hot weather or high winds, if there is much traffic on the road. Sprinkling is the only thing that will keep a road from breaking up in long continued dry weather.

The treatment of gravel roads compacted either by traffic or horse rollers, differs very little from that pursued with earth roads. When the gravel is over 1 inch in diameter, it is almost impossible to keep the road-bed from breaking up when dry, and ¾ inch would be a better size, unless continuous watering can be depended on in dry weather. Small gravel (and the same remark applies to metal for Macadam) makes a pleasanter road for travel, and can be more easily kept in order.

St. Nicholas Avenue, which will be mentioned further on, was made from nearly clean Roa Hook gravel, by the aid of a 15-ton roller, but with a horse roller it will be necessary to add clay, loam or some softer material, to any hard or clean gravel to act as binding. W. H. Grant, Member of the Society. in his valuable description of the roads of Central Park, says of Roa Hook gravel, "it being more than ordinarily clean and hard, bears an intermixture or adulteration of 20 to 25 per cent. of inferior material to perfect its binding properties." These roads have a foundation of rubble stone, not so firmly packed as Telford specified, covered with quarry chips and hard pan, which was rolled with 2-horse rollers, 6 feet long. "This is thoroughly done to prevent the gravel filling the cavities of the rubble bottom, so that its cellular character may remain unimpaired to facilitate drainage." The gravel was applied in two or three successive layers, making a depth of 4 to 6 inches. Each layer was rolled with a 2-horse roller, and the last with one weighing 6½ tons, 5 feet long, giving 217 lbs. per inch pressure. These roads, which were thoroughly underdrained and side guttered, have long been famous for their excellence ; they are pleasanter for light travel than Macadam, and are easily kept in repair, except in wet weather, when they become muddy, and when neglected, the larger pebbles make a rough road for buggy riding.

For horse rolling binding should be applied as sparingly as possible, and on the last layer, after it has been compacted, simply as a glaze to hold the stone ; if it contains clay, it should be as moist as possible, not to stick to the roller.

The so-called Tompkins Cove gravel, which is much used for entrance drives to gentlemen's places about New York, is a broken lime

stone, apparently of the cement series. It is usually spread over the road, and compacted by the wheels. The darker colored stone is very pleasant to the eye, and it readily makes a smooth wheelway singularly free from either mud or dust, even when subjected to rather heavy traffic, though it is too friable for economical use in such situations. Its performance is so different from that of the ordinary limestones that an analysis is appended:

Lime	60.20
Alumina	11.22
Silica	6.13
Magnesia	10.45
Carbonic Acid	8.00
Water	4.00
	100.00

MACADAM.

Roadways surfaced with broken stone have been in use for a long time, but Macadam, about the end of the last century, systematized their construction and maintenance, effecting such an improvement in English roads that his name seems indissolubly connected with roads of this class. His plan seems to have been essentially, to have a well drained, uniform road-bed for the reception of small, clean stone of uniform quality applied in thin courses, deprecating any addition of earth, clay, chalk, or other matter that will imbibe water and be affected by frost, under the pretense of binding it.

He held that a surface of an inch square or a stone 6 ounces in weight was of the maximum size for road metaling, anything larger than that being mischievous, and that 10 inches of solid Macadam was sufficient to carry any load, rather prefering a soft substratum, saying that the cost of maintenance on a morass was to the cost on a rocky foundation in the ratio of 5 to 7.

Telford differed from Macadam in his views, how much may be best seen from one of his specifications taken from Parnell's Treatise on Roads: London, 1833, p. 147 *et seq.*: "Upon the level bed prepared for the road materials a bottom course or layer of stones is to be set by hand in the form of a close, firm pavement. They are to be set on their broadest edges lengthwise across the road, and the breadth of the upper face is not to exceed 4 inches in any case. All of the irregularities of the upper part of the said pavement are to be broken off by the hammer, and all the interstices to be filled with stone chips firmly wedged or packed by

hand, with a light hammer. The middle 18 feet of pavement is to be coated with hard stone as nearly cubical as possible, broken to go through a 2½-inch ring, to the depth of 6 inches, 4 of these 6 inches to be first put on and worked by traffic, after which the remaining 2 inches can be put on. The work of setting the paving stones must be executed with the greatest care, and strictly according to the foregoing directions, or otherwise the stones will become loose, and in time may work up to the surface of the road. When the work is properly executed no stone can move : the whole of the materials to be covered by 1½ inches of good gravel, free from clay or earth." Of which Parnell says, "The binding which is required to be laid on, on a new-made road, is by no means of use to the road, but, on the contrary, injurious to it. This binding by sinking between the stones diminishes the absolute solidity of the surface of the road, lets in water and frost, and contributes to prevent the complete consolidation of the mass of the broken stones."

As regards the foundation, Macadam seems to have the engineers of France and England mostly on his side. In this country, it is believed Engineers generally prefer a Telford foundation. Neither Macadam or Telford used a roller, both depending on the grinding action of the wheels of wagons to compact their roads ; and it was probably to lessen the brutal pulling through loose metal that Telford used his coating of gravel.

Road rolling was first brought prominently before English readers by Sir John F. Burgoyne, in a paper written in 1843 (which is reproduced by Law & Clark). And the best American practice very fully endorses his views. He recommends a weight, as the greatest attainable, of 261 pounds per inch run of roller, the use of stone dust or sharp gravel for binding and watering. His opening sentence, "the importance of rolling roads, either newly constructed or when subjected to extensive repairs, seems never to have been duly appreciated," is still true in England, for the writer saw loose stone kicking about Great George street, in front of the Institute of Civil Engineers, for over a month.

It may here be said that writers on roads have not always kept the differences between the possibilities of construction of the three types of Macadam roads (viz., traffic made, horse rolled and steam rolled) sufficiently before their readers. The grinding action of wheels will pack the hardest stones of proper size, and make a firmer road-bed than if a softer material is used for binding, but about one-third of the material is worn

out in the operation, to say nothing of the wear on horses and wagons. On account of the digging action of the horses' feet when drawing heavy rollers, horse rollers will only compact and bind the softer rocks, without the aid of binding material, and no steam roller is known heavy enough to bind trap and the harder granites, without such aid.

The only circumstance that can justify an Engineer in depending on traffic to make his road (except in the case of small, thin patches) is an inability to procure a roller; and then the material should be applied in very thin layers, for, in addition to the waste of material, the cost of raking and leveling a new road will nearly equal the cost of horse rolling, the surface will never be as good; and, as dung and dust will be ground in with the stone, it will be more affected by wet and frost. In addition, as a road is made for economy and convenience of transportation, the damage to horses and vehicles should not be allowed, even if it made a better road.

While a horse roller will make a much better road than traffic will, it is inferior to a road rolled by steam rollers, for about 260 pounds per inch run of roller seems to be the greatest weight practically attainable by horse rollers, which is not sufficient to make a road of trap and the harder stones, without the use of some softer materials as binding, which presents the objections stated by Parnell, even under the most careful system of application.

With a steam roller the weight applied can be made equal to the requirements. The horses' feet do not cut up the metal almost as fast as it is arranged and compacted by the roller. Hard binding can be used, making the roadbed nearly homogeneous and impervious to water, preventing movement of the stones on each other. Lastly, the frictional action of the driving wheels arranges and compacts the stones better than a greater rolling weight does, making, in fact, an entirely different wheelway in its wearing and sanitary aspects.

The best horse-rolled road known to the writer is the Southern Boulevard, built by Wm. E. Worthen, Member of the Society. The earth was compacted by rolling, on which 2½ inch trap was placed in one 6-inch and one 4-inch layer, when both layers were compressed as far as possible by the use of 2-horse rollers; 2½ inches of screenings were spread over and rolled in. As water was not easily attainable on the line of the road the screenings were thoroughly wet before they were carted to the road. This wheelway, which was fourteen or fifteen feet

wide, stood seven years, almost entirely without care, under a heavy carting traffic, and a good deal of light driving. But the road was never as solid as those made with steam rollers and properly puddled, opening more with the frost, and having more loose stones on it.

The writer built some horse-rolled road on an old Macadam road which was substantially worn out. The material was a syenitic gneiss, quite hard and broken by hand to pass through a 2-inch ring. It was generally laid on 6 inches thick, in one course, though where the old metal was mostly gone, two layers of stone were used. The rollers were 6 feet long, weighing about 2 tons light and 3½ loaded. They were used with 2 horses light and 4 horses heavy. The stones, which were broken on the side of the road, were handled with 10-tined forks, the tine 14 inches long, 1¼ inches apart, known as "tanners' forks." These forks, with a little care on the part of the laborer, left nearly all the dust and small stone behind (the average wear of tines was one inch for 300 cubic yards handled), so that the stones went into the road fairly clean, where they were rolled; the shoulders being at the same time made up with good earth, until they were fairly compact, when the dust and small stones, left by the forks, were spread on the surface which was again covered with about ¾ of an inch of preferably clayey soil, where it was procurable, which was rolled thoroughly. If the binding was sufficiently damp, the road stood very well, showing few loose stones; but when it was too dry or the earth was washed into the body of the metal, by heavy rains, the work was not at all satisfactory.

The labor account per mile of wheelway, 14 feet wide, equal to 8 213 square yards on which 1 260 cubic yards of broken stone were placed, was as follows, the days being of 10 hours each: Spreading and forming material and loading dirt for shoulders and binding, with sweeping the old Macadam clean, but no picking, 229.5 days' labor. 24 days were occupied rolling, 13.2 with 2-horse and 10.8 with 4-horse teams.

This road, with the shoulders, was 18 feet wide and the teams travelled at the rate of 2 miles per hour; allowing 90 per cent. of the time as productive, the roller passed 144 times over the surface. The mean weight of the rollers per inch run was only 75 lbs., and the maximum 100 lbs., a weight altogether too light for either economical or thorough work.

One end of this road was on a hill, with a rise of 110 in 1 500 feet; the maximum grade being at a rate of 8 per 100. It was not judged

advisable to depend on natural moisture for the binding, and a steam pump was procured, by the aid of which the metal was made thoroughly wet before the binding was applied. The binding used on the hill was a light loam; but considering the grade, the finished wheelway was as good as when heavier loam had been used, relying on the moisture in it.

In England there does not seem to be any well-established system of road making. Some of the Borough surveyors apparently do not believe in any rolling at all; others, after carefully picking up the old road-bed, put on the stones, and after more or less traffic has passed over it, put on a 5-ton roller 5 feet long, drawn by 4 to 6 horses. The binding called "hoggin," which is a loam with coarse sand and gravel in it, is apparently not always applied in the case of repairs. Appendix No. 1 is referred to for specifications for a new road.

The repairs of the wheelway of the Victoria Embankment were made by first thoroughly picking up the old road-bed and then coating it with clean Guernsey granite, hand broken, to go through a 2½ inch ring, entirely free from dust and debris, and nearly so from small stone. Guernsey granite is about as hard as trap. It was rolled with 15 ton Aveling & Porter's rollers. When compacted, hoggin was added in sufficient quantity, and with enough water to flush the material into all the interstices and leave a surplus about the thickness of grout on the surface, which was swept with brooms in front of the rollers. The same system was employed at Russell square and Bedford place.

This did not make a good Macadam road; the hoggin acted as a lubricant, allowing the stones to work on each other under the traffic. There were loose stones on the road; five weeks after the road was completed, a kick would move the stones in front of it for fully a foot; when the surface was drying, the outlines of many of the stones could be seen by the cracks in the mud covering them; the angles of the stones were already wearing off, and after a rain, on sweeping the road, the gutters were filled with mud 4 to 6 feet wide.

It was said that dissatisfaction was felt with this system, and during the past summer an effort was made to make a road simply by rolling, without the aid of any binding. The success was no greater than that of Mr. Grant, 20 years ago, in the Central Park.

In Liverpool a mixture of broken stone and coal tar pitch is laid—one ton of pitch that will just run at 100° F., is mixed with 70 galls. of dead oil and added, hot, to 5 cubic yards of stone. The stone is *dry*,

but not heated; the mixture is rolled with a hand roller in short lengths. The surface is very good, making a favorite road for velocipede riders, and it can be swept without danger of dislodging stone, but it does not seem to have the wearing qualities of a well puddled trap road. Some laid three years in Basnat street, now requires pretty extensive repairs.

In Scotland a concrete has been used with Portland cement, for binding; the surface was very good, but when the road commenced to break, it went to pieces very fast.

M. Malo speaks of the Macadam in Paris, as follows: "Day by day, they try with incalculable efforts to perfect Macadam. They have perfected their watering in summer and sweeping in winter; they have substituted, at great cost, granite in place of limestone; they have multiplied their road laborers; each morning the devastations of the day before are repaired with incredible rapidity, but when the stream of traffic again covers the street, the scourge (*fleau*) recovers its rights, and during 300 days of the year the roadway becomes an ocean of mud or a mass of infected dust." In other words, a poor system of construction, but probably the most thorough system of maintenance to be found anywhere. A. Debauve, in his "Manuel de L'Ingénieur," after speaking of the immense capital invested in the old Roman roads, says: "The tendency now is to have the thickness only that which is necessary for resistance, to suppress the foundation, and, in one word, to economically establish the roadways and maintain them afterwards in a fit state by incessant repairs which the ancients did not know of."

In Paris the Macadam roads are composed of water-worn flint pebbles which are compacted by ramming with a rammer 8 inches in diameter, weighing 70 lbs., and horse rolling with the aid of sand and water, *meulière*—a kind of burr mill stone—and porphyry, the two latter are generally steam rolled. These materials are used, according to Debauve, in the following proportions, viz., flint, 10 per cent.; meuliére, 67 per cent., and porphyry, 23 per cent.

Macadam roads in Paris as in London, are the roads of luxury. On many streets, the centre, for a width of 19 feet, is covered with Macadam, while the sides, for a width of 13 feet each, are paved with stone sets or asphalte. The Avenue des Champs Elyssés, Place Concorde, and some of the Quais are of flint; other of the Quais and Rue de Rivoli are of harder stone, while the Avenue de l'Opera, Boulevard Haussmann, etc., have Macadam only in the middle.

The French, who use the Gellerat roller in Paris, specify a maximum weight of 448 lbs. per inch run and a maximum speed of 2.3 miles per hour. The rolling is done by contract (the city furnishing water) at a rate per ton mile varying from 15.26 to 7.63 cents according to the amount, with an increase of $\frac{1}{3}$ in price where the grade exceeds 6 per cent.

The thickness of metal rolled varies from 12 inches on new roads to 2 inches on old. It is maintained that the work of compacting a cubic yard of the same stone is independent of the thickness when that varies between 2 and 6 inches and is from 2.7 to 3.27 ton miles per cubic yard.

From a table (p. 308) in the notice of the objects, &c., exhibited by the City of Paris at the Exhibition of 1878, it is seen that the mean weight per inch run of the steam rollers is 448 and 336 lbs. and for the horse rollers 263 lbs. Also that the ton miles necessary to make a square yard of porphyry wheelway, or to compact a cubic yard of the same metal, are as follows: the mean for the two models of machines weighing 448 lbs. per inch run was, per square yard, with thickness of 3.9 inches, 0.41 ton miles, while for the roller of 336 lbs., with a thickness of 2.8 inches, 0.234 ton miles were required, or 3.78 and 2.99 ton miles per cubic yard respectively, and for horse rollers where the thickness was 2.6 inches, the ton miles required were 0.194 per square yard and 2.69 per cubic yard. The amounts consolidated per ton per hour are in the following proportions: 467 for the heavy rollers, 539 for the light roller, and 297 for the horse roller, and the number of passages of the rollers were 98.5, 75 and 92.

It appears from these tables that the smaller weight is the more advantageous, and that horse rolling is cheaper than steam rolling; it is added, that, on account of their superior celerity, the steam rollers are almost exclusively employed.

No statement is made as to the relative wear of stone rolled by the different machines.

About 24 per cent. of sand is used for binding. The surface is allowed to wear down until 2 to 6 inches of metal is put on.

Repairs were being made on Boulevard Haussmann by a 5-inch layer of *meulière*, very nicely hand broken to pass through a $2\frac{1}{4}$-inch ring, free from dirt and small stone; the roller had a weight of 360 lbs. per inch. After a few passages had been made over the stone, very clean sand was spread on, which was shortly wet by a hand hose. The water was not at

first applied in sufficient quantity to flush the sand thoroughly into the interstices, but the sand was just damp enough to pick up the stones. The speed of the roller was thought to be fully 2¼ miles per hour. The binding was not so thoroughly wet as on the Victoria Embankment, nor was the metal rolled as much. When the street was thrown open to traffic the consolidation was about at the point at which in this country we would commence applying screenings, stones were picked up by the wheels, and a light kick would move the stones for from 1 to 1½ feet in front of it.

On the Avenue de l'Opera, the centre of which is covered with broken porphyry, the stones presented the same evidences of motion on each other, mentioned as seen on the Victoria Embankment.

In New York City there are, including St. Nicholas avenue, 27.99 miles or 921 400 square yards of steam rolled Macadam roads, besides the horse rolled roads in the Central Park and the Twenty-third and Twenty-fourth Wards, of which 17.75 miles or 718 200 square yards are on Telford foundations. They were commenced in 1869, and mostly finished in 1876.

The first had a 5-inch layer of gneiss laid on the Telford, on that a 5-inch course of trap, both broken to go through a 2½-inch ring. The trap was and is machine broken, and the screenings, *i. e*,, dust and stone that passes through a 1-inch or 1¼-inch aperture, are used for binding. At first it was held that these should be used as sparingly as possible, but experience has shown that the roads wear better and have less loose stones on them when the interstices are fully filled with screenings, and the size of the stone in the top course is preferably from 1 to 1½ inches. The general practice now is to put on the stones in two courses when the thickness, compacted, is 6 inches or more, and roll the first course until it will settle no more, then add the last course, and after it has settled, screenings are added, at first coarse and then fine, and after thorough rolling, the whole is puddled by a copious addition of water. This is accomplished more thoroughly and satisfactorily in hot, dry weather. After the road is puddled ¼ to ½ inch of screenings are spread over it, and after drying an hour or so the traffic is turned on.

For the old style of construction Sixth avenue, between One Hundred and Tenth street and Harlem River, may be taken as a type, having the materials and courses as above mentioned. It was rolled with

Aveling & Porter's 15 ton rollers, of the old pattern, in which the weight is nearly equally divided between the steering and driving wheels, which cover 6 feet, giving a bearing weight of 467 lbs. per inch run. As near as can be ascertained, $24\frac{6}{10}$ hours, at $1\frac{1}{2}$ miles per hour were occupied in rolling 1 000 square yards, giving for the work done 0.553 ton miles per square yard, 2 246 ton miles per cubic yard, and 129.8 trips of the roller over the surface.

Avenue St. Nicholas, which, as mentioned above, was made from Roa Hook gravel, had a rubble foundation, and it was intended to have 6 inches of compact gravel, but the foundation settled so that in some instances the gravel is 14 inches thick. The practice was to lay the gravel on and wet it thoroughly over night. It was rolled the next day until the water was forced to the surface. A 15-ton roller was employed about 26 hours per 1 000 square yards, besides some horse rolling. A little hard pan was used for binding. The intention was to make a road for fast driving, but the surface was as hard as that of a Macadam road, though much smoother.

The data for these two avenues depend on the memory of the engineer of the roller, and are approximate only.

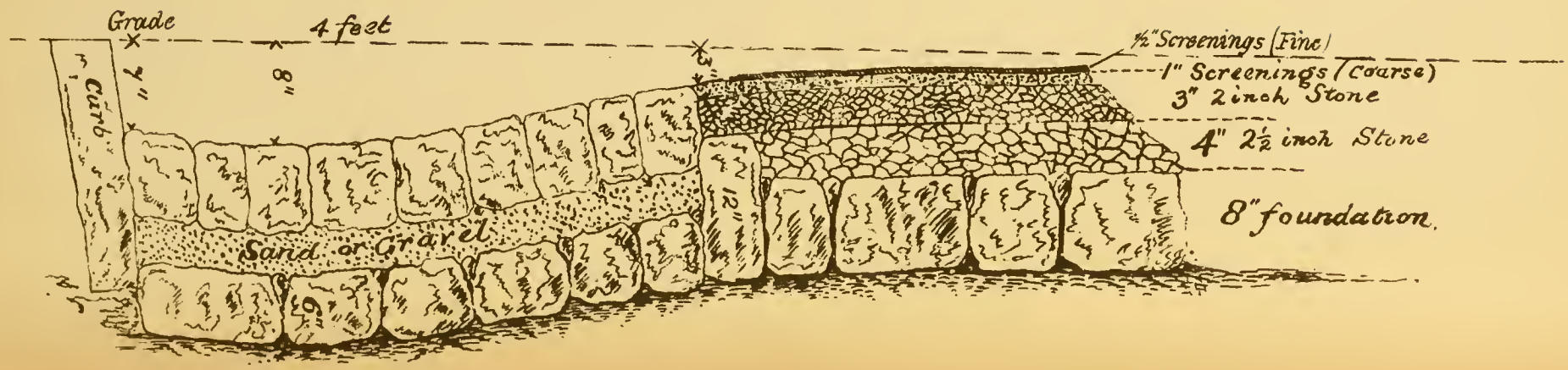
The Telford Macadam on Fifth avenue has 8 inches of Telford, 3 inches of $2\frac{1}{2}$-inch trap, 4 inches of 2-inch trap, 1 inch of coarse screenings, and one-half inch of fine screenings, when completed. The wheelway is 40 feet wide between curbs, with 4 feet gutters on each side, of trap blocks. (For Specification see App. 2 and Plate No. XXIV.)

Mr. F. H. Hamlin, for some time Engineer in the charge of Roads and Streets in New York City, to whom I am indebted for these data, intended, by the use of the $1\frac{1}{2}$ inches of screenings, to have the road as smooth and pleasant for riding as Avenue St. Nicholas, without the tendency to mud in wet weather. The work was let in two contracts, at $1.30 and $1.49 per square yard. The average time employed setting a square yard of Telford was $20\frac{1}{2}$ minutes. Spreading the stone and screenings, per square yard, $1\frac{2}{10}$ minutes. About $58\frac{6}{10}$ hours rolling were given per 1 000 square yards; and the work done, allowing the effective speed to have been $1\frac{1}{4}$ miles per hour, was 1.099 ton miles per square yard, and 4.709 ton miles per cubic yard of compacted material, if there had been no settlement, but there was an unascertained settlement.

These roads are maintained by spreading very thin layers of fine Roa Hook gravel over them and watering. The first roads were built with

Section of Pavement for 5th Avenue from 59th to 72nd Street

Width of Avenue 40 ft.



F.H.Hamlin Engineer.

PLATE XXIV
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an idea that as small a quantity of screenings as possible should be used, and in dry weather, the stones which become prominent by wear, are liable to kick out; the fine gravel prevents this, and by retaining water, sprinkling is not necessary so often. The fact that the travel concentrated near the gutters, where this gravel, by the action of rain, becomes thickest, in connection with the demands of owners of fast horses, who wished a softer road-bed, led Mr. Hamlin to cover one of them with a coating three-eighths of an inch thick, consisting of three parts of coarse sand and one part of strong clay. This has been on the road through two winters, and the road-bed is still firm, and it has been applied to others.

Under Mr. Hamlin's charge the average cost of maintaining these roads has been $4\frac{2}{10}$ cents per square yard per annum for the labor and material of road covering, cleaning and sprinkling, with incidental repairs and supervision. None of them have been resurfaced with broken stone, excepting a portion of the Western Boulevard, the first built, and two or three patches of 100 feet or less in length, which cost 46 cents per square yard.

It is very difficult to estimate the traffic on these roads. On a fine day 3 000 vehicles may pass over them, while at other times there may be not more than one-tenth of that number.

In repairing the Southern Boulevard, mentioned above, the trap broken to go through a 2-inch ring, was laid on 6 inches thick in one course; $38\frac{2}{10}$ hours rolling was given per 1 000 square yards. Allowing the speed to have been $1\frac{1}{2}$ miles per hour, the work done on it amounted to 0.859 ton miles per square yard and 5.177 ton miles per cubic yard; 201 trips were made over the surface. The Macadam was 15 feet wide, and some of the rolling was on the shoulders, though probably not enough to affect the result materially. The work was done in July and August, and a little less than 0.6 cubic feet of water per square yard, (3.5 cubic feet per cubic yard) were used in compacting and puddling. About one-third screenings were added. Those portions of the road that had the most work done on them are now in the best form, after nearly two years without any care; and generally the more thoroughly the trap roads were rolled the better do they wear.

It should be understood that there was no counter on the wheels of the rollers, and the speed is the result of estimation, interfering with accuracy in the estimate of the number of ton miles performed. The

rollers used in the above mentioned works were 15-ton Aveling & Porter's (old pattern), and though they are understood to bear equally on the driving and steering wheels, the writer thought the driving wheels nearly twice as effective as the steering wheels.

The superiority of the American Macadam roads is partly due to the greater amount of work put upon them; the binding, which is of the same hard material as the metaling, almost completely fills the interstices between the stones and the entire mass is thoroughly compacted and nearly homogeneous. It is only while the frost is coming out of the road in the spring that the stones wear upon one another at all. The process of puddling gives a very smooth, hard firm surface, resistant alike to wear and the infiltration of water, which is of equal advantage to the stability of the foundation and from a sanitary point of view. By the use of the steam roller the stones are compacted with a small amount of wear to their angles and an entire freedom from mud and dung, their only weak point being that in long-continued dry weather the larger stones are apt to get dislodged from the surface, some moisture being necessary for the full cohesion of the binding. No amount of wet weather, unaccompanied by frost, seems to injure them, unless mud works up through the foundation, and their imperviousness under the most disadvantageous circumstances is well illustrated by the practice of Mr. Hamlin, as cited above.

The English roads are rolled less, and the binding, though cheaper in cost and in the matter of rolling and spreading, is, when thoroughly wet, to a great extent an element of weakness to the roads, allowing a large part of the wear to be internal, and failing to hold the stones from dislodgment, either by the wheels of vehicles or the brooms of the sweepers. When dry it can have neither cohesion nor resistance, its use being confined to the time it is slightly damp.

The roads in Paris seemed to be less thoroughly compacted than in London, but the binding was better, and if it had been applied dry, after the stone was nearly compacted, and only wet at the last rolling, it would probably be more effective. As it was, the grain of the sand seemed to have been broken down during the rolling of the stone, and as, like the English made roads, the stones move on one another, it must be still more thoroughly ground up.

The maintenance of roads in Paris is much more effective than in London. It consists essentially in washing rather than sprinkling them,

and sweeping the mud and debris of the surface into the gutters, where it is washed with a copious flow of water, the mud and fine sand going into the sewers, the coarser sand being retained for use on the streets. Most of the work is done at night and in the early hours of the morning. While there is on the average (judging from the amount of mud relative to the traffic) rather more wear than in London, no loose stones were seen on the streets, except when newly mended, men apparently being always present with brooms, rammers, and sand, to repair any place that showed signs of weakness. On the Avenue des Champ Elysées, and other flint roads, the surface was often swept with birch brooms having long and slender twigs.

In London the maintenance is neither so constant or skillful; the roads are watered in dry weather, and swept or scraped in wet, with an occasional addition of sand or fine gravel.

There seems to be no accessible accounts of the cost of repairs and maintenance in London. W. S. Till, the Borough Surveyor of Birmingham, in one of his reports, says: "Mr. Howell, Surveyor to the Vestry of St. James, Westminster, informs me that the cost of maintaining, &c., the surface of Regent Street, London, which may be considered one of the best Macadamized roads in the Kingdom, and in which nearly every description of pavement has been tried, is $0.87 per square yard per annum; it has, however, been much higher." It is not known whether Regent Street was then steam or horse rolled.

In Paris, the expense of maintenance had reached on some of the streets 16 francs per square meter ($2.57 per square yard) per annum, and it was resolved to pave all but the middle 23 feet, in streets 48 feet wide, and to pave narrow streets and gutters, and in 1871 it was resolved to pave streets where the annual expense of maintenance was over 48 cents per square yard, excepting those avenues which are used by carriages of luxury. This, however, was not fully carried out.

Many adverse criticisms are made on Macadam roads by parties who judge of their value mainly from reading statements regarding European Macadam. A well made trap road, when properly watered and maintained, is, after an earth road, the pleasantest and safest road known. In this locality a road 15 feet wide would give suburban residents the same easy access to their railroad stations in the worst winter weather as in summer. And for streets of residence, where the inhabitants would keep them free from garbage, both for quiet, safety to horses, and on sanitary grounds, they are preferable to the ordinary paving.

It is possible that with thoroughly compacted and bound roads, the English and French Engineers would look with more favor on Telford foundations, for with the roads we make, the wear between the Macadam and Telford must be very slight, the pressure of a wheel being spread over a large surface. They are preferred here because they give an equal depth of foundation more cheaply than with broken stone, and as in this country municipal appointments of Engineers are sometimes influenced by political considerations, the general desire is to build as solidly as possible.

One objection that may be urged against the Telford foundation is the fact that it does not have a solid bearing on the earth roadbed, and when the road is worn thin the spaces between the stones may become filled with water and mud, which will work through the foundation into the broken stone, hurrying the disintegration of the road.

The English Engineers often use "hard core," a mixture of brick rubbish, old plastering and broken stone, on a clay soil, to prevent the mud working into the metaling.

This result was accomplished by the use of six to eight inches of fine sand on Mott avenue, New York, which was built at the joint expense of the City and private parties. The regulation of the surface required a maximum cut of two and a half feet and a fill of four feet; the soil was a heavy loam, thoroughly saturated by the fall rains, which continued until the work was completed, and it was desirable to Macadamize it immediately. Rough gneiss rock was placed on the layer of sand and rolled to an even surface, with a thickness of about eight inches, and on that a scant six inches of loose 2-inch trap, to which thirty per cent. of screenings were added. The bottom was very treacherous; on about half the road it was not safe to stop the roller, which broke through in two instances in spite of the care exercised. Nor could the road be rolled long in one place; but as soon as the surface began to weave in front of the roller it was given a rest, and the roller taken to another part of the road. In spite of this the road was compacted and the surface puddled satisfactorily, except in one or two small patches. It has stood the freezing and thawing of two winters without receiving or requiring any attention.

It is held that the success of this operation, so contrary to the teachings of the books, was due to the layer of fine sand being impervious to the mud, which without it would have been over the top of the Macadam a long time before it was puddled.

The deductions of the French Engineers from the table cited on page 12 should have been strengthened or modified by a statement of the wear of the different work done. And their principles of road construction are dissented from, because the writer believes that the horse roller made road does not differ so much (after both are compacted) in wearing value from the road specified by Macadam as it does from the road properly made by a steam roller; that all binding should be fully as hard as the stone, and that the better road is made with the heavier roller per inch run, as far as his experience has gone, *i. e.*, up to 460 pounds. And, in addition, that up to that weight the ton miles rather than the load should be altered on account of the greater or less hardness of the rock employed for road construction.

It is believed that no one who has used the two styles of 2 ton rollers mentioned, viz., 3 feet and 6 feet long, doubts that the 3 feet roller will do better work than can be accomplished by the 6 feet roller without loading.

Under the writer's direction the same quality of syenitic gneiss mentioned on page 9 was rolled with a 15 ton steam roller, with binding of the same quality in both cases. There were only about 200 cubic yards of it, and on account of the traffic passing, it was impossible to keep an exact account of the work done, but the road is very satisfactory, and from it the writer thinks that a few passages of the steam roller over the horse rolled road would add materially to its life, besides greatly reducing the number of loose stones on its surface.

Some refuse Westchester marble (a very soft rock) was delivered on some of the roads at about 25 cents per cubic yard, and hand broken in place at the rate of about 1 cubic yard per hour. A portion was rolled before any traffic went over it, some after about two weeks of traffic and some after six weeks; of the rest, part was horse rolled and part compacted by wheels; the quality of the stone, traffic, etc., were very nearly the same; that not rolled by the steam roller soon wore into holes, the first mentioned is, after standing two winters, in very fair surface; the others decreasing in the order in which they are mentioned. This difference is so noticable that anyone could pick out their sequence as mentioned.

Shortly before this, however, the writer very nearly made a mush of some micacious gneiss in trying to reduce the crown of a road covered with it.

Late in the fall a portion of the Southern Boulevard was repaired with 2 inch trap, screenings, and a 2 ton horse roller. After the metal was compacted a thin coat of clay hard pan was added, which froze solidly that night, and a day or two after was covered with snow which staid on till spring, thus giving it the most favorable surroundings possible. In the summer there was but little difference between it and the steam rolled part; but by fall it had commenced to deteriorate, and now its surface is but little better than that made seven years before.

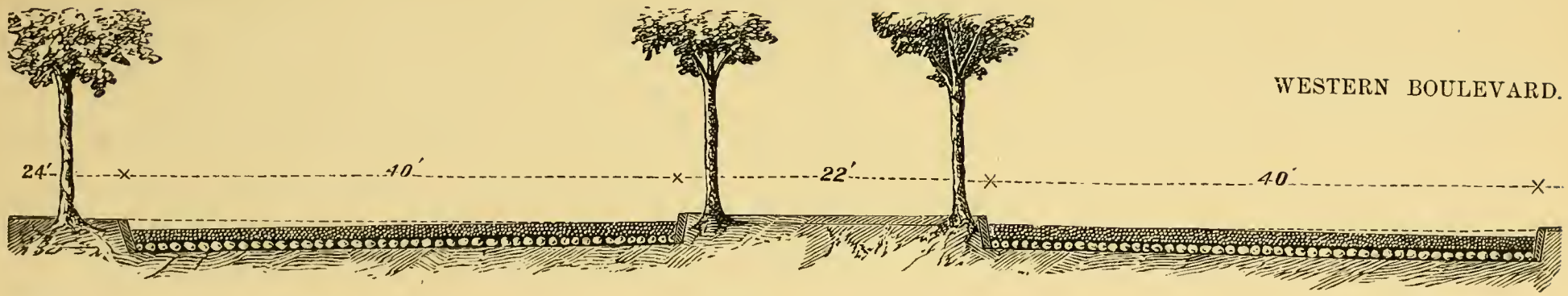
Both the English and French prefer hand-broken stones for Macadam. An experienced breaker will make better shaped stones than any crusher can, and hand breaking would afford employment to labor. The hand broken stones mentioned above were delivered by contractors at $2.00 per cubic yard; the men who broke receiving on an average 82½ cents per yard. One man was thought to have broken at the rate of 4.5 cubic yards per day; about 6 to average 2½ yards or more. They stood, using hammers weighing 1¾ to 2 pounds, on very flexible handles. The average of all who worked could not have been much over 1 yard per day.

On the other hand, there is not enough fine stone for binding, what there is, is full of dirt, and machine breaking is cheaper; the cost of crushing trap with a Blake crusher, after it is sledged, being understood to be less than 70 cents.

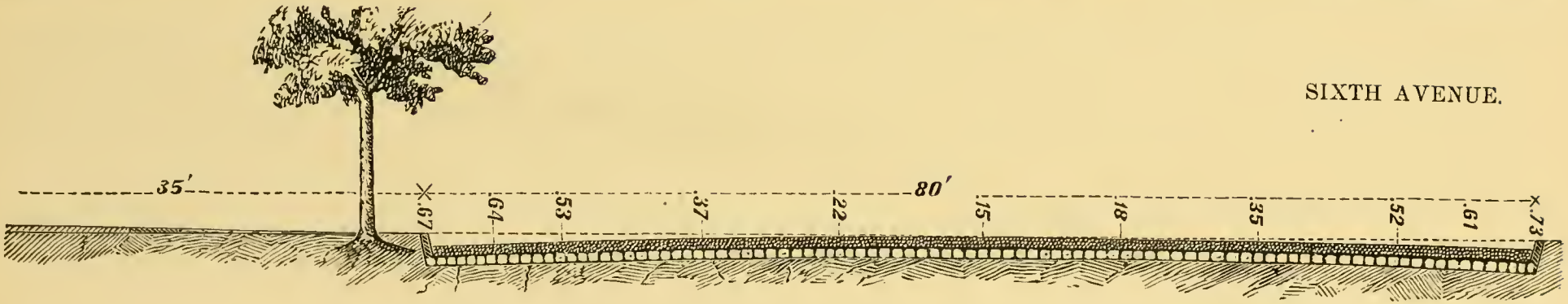
The crown or transverse section of a road should depend on so many different considerations that no general rule can be drawn for it. With Macadam made from hard material, the less crown, on many accounts, the better, as the surface is benefited by being kept damp. In narrow wheelways, particularly, an excessive crown throws all the traffic, as much as possible, in one line, whatever the material may be. On the other hand, in curbed streets, if the road is too flat, the heavy traffic tends to concentrate near the gutters. The crowns given to dirt roads are intended to drain off the water, but the longitudinal ruts soon defeat that object.

Transverse profiles of the Western Boulevard and Sixth avenue, New York City, are shown (Plate XXV). On the former, though the transverse slope is so slight, it is perceptible to a person riding in a vehicle with longitudinal seats, but is not noticeable when on a transverse seat. The cross section of Sixth avenue shows the surface as the road was constructed by M. A. Kellogg, Engineer, in 1872 and 1873, with the

PLATE XXV.



WESTERN BOULEVARD.



SIXTH AVENUE.

crown at the same height as the top of the curb stones, and the figures above the dotted line joining the curbs show the average distance of the surface below street line, as found by careful levels taken this spring between 123d and 124th streets, a point where no broken stone had been added, the wear at the crown being 0.15 foot, or about ⅓-inch per year. The road is not too flat, as it now stands, to shed the rain fall.

The amount of water the writer found necessary to keep earth or Macadam roads from becoming dusty, was, for a well maintained earth road, at the rate of 71.3 cubic feet per 1 000 square yards, applied twice a day, or say 143 cubic feet per day. In very hot or breezy weather this was not quite enough.

On the Telford roads of this city, 25 cubic feet, applied four times a day, are necessary per 1 000 square yards, say 100 cubic feet per day. One water cart, holding 79 cubic feet, waters 35 000 square yards four times a day, keeping it free from dust, except during windy weather.

In Paris about 27 per cent. of the surface is watered by hand hose. These are made of iron pipes about 6½ feet long, each end supported on castors and connected with leather or rubber couplings; the working end being a piece of rubber hose. Its cost is one-half that of watering by carts holding 46 cubic feet.

Stone Pavements.

The City of New York is largely paved with the Belgian pavement, *i. e.*, truncated pyramids of trap set in coarse sand. The sand soon becomes saturated with the water and mud of the streets, and the blocks working under the traffic become rounded. It is impossible to keep such pavements in fair surface, and they are about as bad sanitarily as pavements can be.

The pavements now laid are of granite or trap blocks, 4 inches wide, 6 inches deep, and 8 to 12 inches long. They have parallel sides, and are laid in sand, probably forming the most efficient pavement for the cost ($1.91 per square yard), to be found anywhere. The open joints filled only with sand are objectionable, however, as forming receptacles for street mud and water.

The Guidet pavement laid in Broadway, with a foundation of concrete, has lasted very well, its increased wear probably compensating for the additional cost of the concrete foundation.

In Paris, the new pavements are of Gris, a hard sandstone, which is neatly dressed in blocks, 4 to 5 inches square, and laid either in

sand or mortar, and porphyry, about 4 inches wide, 6 inches deep, and 8 inches long, generally laid in mortar.

The best granite pavements are found in England. In London, where the soil is clay, the usual practice is to lay a foundation course of "hard core" which is well compacted by rolling, &c., and the stones are set on this in 2 inches of sand. The better class of pavements, on clay, have 3 to 6 inches of hard core, 9 inches of concrete, and 2 inches of sand. Col. Haywood, where soil is sand or gravel, puts down 9 to 18 inches of broken stone, or 9 inches of concrete, saying that there is little difference in the stability of the two foundations, but the concrete is apt to be replaced in a more satisfactory condition when the street has been opened.

In all the better class of London pavements, the sets are 3 inches wide, neatly split out with parallel sides, and set in blue lias lime grout; Aberdeen granite being chosen in preference to harder varieties, as it wears rough. Though Col. Haywood determined that the duration of the same stone varied directly with their size, these narrow sets are preferred, as making a smoother road, affording a better foothold for horses, and increasing the quietness and general comfort. The practice is to take up the sets when their surfaces become rounded, and redress them, after which they are relaid in streets of secondary traffic. The spalls are useful for foundations and Macadam. Col. Haywood estimates the total life of such paving stones to be 29 years.

In Liverpool, Geo. F. Deacon prefers the Welch traps and granites which are rather harder than our trap. The pavement of North John Street, which has a traffic of 4 000 vehicles, averaging 3 tons each, per day, is of trap blocks, neatly split out, with parallel sides, 6 inches deep and 3¼ x 3¼ inches on the face, set on 10 inches of concrete, the joints are filled with gravel, about the size of a pea, free from sand, and then run with coal tar pitch. It had been paved very close, and the sets were so firmly held in place, that there was hardly any rounding of the surface last winter, though it was laid in 1872. The surface was admirable, and showed very slight wear, and on sanitary grounds, it is probably unequalled by any other pavement, except compressed asphalte, for there can be no percolation of the surface water. The only signs of failure shown by this pavement, is where the boiler of the "Montana," weighing with its 4-wheeled truck 59 tons, passed over it, crushing some of the sets, and showing that stones 3¼ inches square on the face, are not large enough to stand loads of 15 tons per wheel.

Mr. Deacon thinks that the 3¼ inch square blocks present too many longitudinal joints and now employs sets 3 inches thick by 6½ inches deep, and 5 to 7 inches long; the specification for thickness is that any 4 of them, when set side by side, shall measure 12 inches, and not more than 14 inches. It is said the specification is filled without extra cost.

Wood Pavements.

In London, the principal wood pavements are Cary's, the Improved Wood, Henson's, and the Asphaltic Wood. Cary's is laid on sand or gravel, a firm foundation being first made. The patent is for dovetailing the blocks on their ends, which is held by the inventor to give the pavement greater stability. The joints are flushed with blue lias lime grout. The advantage claimed for this pavement is the ease with which it can be repaired, the method being apparently to take out the defective block or blocks, cut off the broomed portion that overhangs the sides of the blocks, put in enough gravel to restore the surface, replace the block with the other face up, and run in the grout. A portion of Cannon street is laid with this pavement. It is said by persons on the street to require frequent repairs. Its power of resisting wear must depend on its foundation, and it can hardly prevent water from working into and through the foundation.

The "Improved Wood" Company started to make an improvement on the Nicholson patent, using two tarred boards, resting on sand, under the blocks. Ludgate Hill, and some other streets, were laid on this principle, but, under the heavy traffic, the two boards acted like a pump, pumping the sand up through the pavement. After trying and discarding one board laid on concrete, they now lay a foundation of concrete 6 inches thick, on which the blocks are placed; the joints are filled with pitch and gravel. This modification apparently makes a good pavement, as seen on Ludgate Hill, where the first pavement has been renewed, and at St. Paul's Church-yard. No company now lays boards as a part of its foundation.

Under the name of Ligneo Mineral Pavement, a company laid some pavement of hard wood, but it proved so slippery that work under that patent has been mostly abandoned. The most work seems to be done, at present, by the Henson and Asphaltic Wood Companies.

In the Henson pavement the 6 inches of concrete is covered with a layer of tarred felt paper, on which the blocks rest, while a strip of the

same material is placed vertically between each row of blocks across the street. Nothing is interposed between the ends of the blocks. After each few courses are laid the blocks are driven close together by a heavy maul. Hot coal tar and pitch is plentifully applied to the upper surface, after which gravel is strewn over it. It will be observed that this pavement presents about as small a joint for foothold as is possible, and to meet objections on this score, at first about every fifth course had a V-shaped groove cut in its top. This has been abandoned by the company, who now lay the surface flush, making a road almost free from noise and nearly as smooth as a compressed asphalte pavement. In answer to objections to their narrow joints, their Engineer asserted that they had changed the practice of the other companies in London from 1¼ or 1 inch joints to as near a quarter of an inch as it is practicable to make them, to the decided advantage of all pavements. They also assert that the tarred felt under the blocks will not wear out, that the pavement is impermeable to water, and that it can be more thoroughly cleaned than any other wood pavement. This pavement was taken up, for pipe connections, in Leadenhall Street and High Holborn. Although it had been raining in the first instance, and raining and freezing in the other, the wood was bright and not at all water soaked; the felt underneath, however, was considerably worn. The claim in regard to cleaning is probably correct.

The asphaltic wood pavement, laid under the patent of H. S. Copland, C. E., has on the 6 inches of concrete a quarter of an inch of tempered Trinidad bitumen, on which the blocks are placed; the joints across the street, which are kept between a quarter and an eighth of an inch, are run with a softer bitumen for about 2 inches, and flushed with lias lime grout, the ends of the blocks abutting against each other; the whole is covered with gravel. The pavement, unless cracked by the settlement of the foundation, must be as impervious to water as one of asphalte, and should stand the traffic very well. On account of its rigid foundation it is more noisy than the Henson, and having a slightly wider transverse joint, it hardly rides as smoothly after some wear, though the difference would not be readily noticed. It should be noticed that the bitumen which is run in the joints makes a firm bond with the layer under the blocks, and more wood is spoiled in taking up this pavement than any other observed.

This pavement was first laid in Cannon Street, between Abchurch and Laurence Pountney Lanes, in July, 1874. It was laid, apparently,

with joints rather over than under 1 inch, and in December, 1878, the edges of each block had broomed over into the joint; otherwise the surface was good, and I could not learn from any source that repairs had been made on it, except when the street had been opened for pipes. The grade is 1 in 90; and in 1873 the number of horses passing over it in 12 hours—from 8 A. M. to 8 P. M.—was 5 350.

The practice in London is to cover the surface of wood pavements several times a year with hard gravel, which is beaten into the ends of the fibres by the traffic, tending to preserve the blocks from wear, and it is claimed, from decay. The wood used is a species of pine—Baltic fir—harder than our white pine and softer than Southern or pitch pine, resembling what is sold in the Chicago markets as Norway pine; it is better seasoned than the pine generally used by house carpenters in this country, and is usually laid without being creosoted, the borough surveyors claiming that the difficulties of inspection are increased by creosoting; but as far as noticed, for renewals and repairs which are made by the companies under their contracts for maintenance, creosoted wood is used; their managers saying that they expect it to add to the wearing qualities of the wood as well as to protect it from decay. The concrete, usually covered with a thin coat of cement mortar, is made of one part of Portland cement to 6 parts of Thames ballast, which varies in size, from sand to pebbles three-quarters of an inch in diameter.

It is rather difficult to arrive at the durability of either wood or asphalte pavements in London, as Col. Haywood, the City Engineer, lets them at a certain price with a provision that they shall be kept in repair for a term of years at a certain price per square yard per annum, a good pavement being turned over to the City at the expiration of the contract for maintenance; the contractor in the meantime replacing the entire roadway, if necessary, as will be noticed under the head of asphalte. This plan has worked so well in the City that the surveyors for the vestries have generally adopted it, so that in London, the wood paving contracts are usually let with the same length of maintenance as for compressed asphalte, and at about the same price, viz.: at a first cost of from $4.38 to $3.90 per square yard, including foundation, but not excavation. They are kept in repair for two years at the contractor's cost, and at the rate, depending on the amount of traffic, of from 36½ to 18¼ cents per square yard per annum for the succeeding 15 years.

From the report of Col. Haywood to the Commissioners of Sewers of the City of London upon asphalte and wood pavements, 1874, page 38, *et seq.*, we find that the greatest duration of any wood pavement was in Mincing Lane, nineteen years and one month; the average cost per square yard per annum having been, in that instance, thirty-five and one-half cents, while the average cost of three heavy traffic streets had been sixty-three and nine-tenths cents. He concludes that, with necessary repairs, wood pavements will last ten years in London.

Law & Clark's Roads and Streets, page 239, gives the wear of three wood pavements at three-tenths of an inch per annum under a traffic averaging 362 vehicles per day of twelve hours for each foot in width of the street. Mr. Clark says it is claimed, in some instances, blocks have worn down in London to a depth of two and one-half inches (the Wells street pavement was only two inches thick, before removal), and suggests eight or nine inches as a better depth than six inches, now universal. The blocks of the Mincing Lane pavement, which lasted nineteen years, were nine inches deep. If we assume that the blocks are six inches deep, and that the road will not break up until they have worn down three inches, there seems no reason why a thoroughly creosoted wood pavement, laid with narrow joints, on a sufficient bed of concrete, with a water-tight stratum interposed, should not wear for about ten years in our streets of heaviest traffic, with a small amount of intelligent maintenance.

There have been several charges made against wood pavements, which are mentioned here, not as a matter of information, viz., that they soon become full of holes, are impossible to clean, are difficult to replace when the street is opened, and that by their rotting the health of the community is endangered, to which may be added that for only a short time do they present any barrier to the saturation of the soil by surface water.

The general practice, as far as observed by the writer, in this country has been to lay *green* or wet pine blocks, more or less thoroughly dipped in coal tar, on a bed of sand, not always thoroughly rammed, with or without the interposition of a tarred pine board, with transverse joints from one to one and one-half inches wide filled with gravel and coal tar, which was theoretically thoroughly compacted. Omitting those which, without the slight pretense of a 1-inch board for foundation, speedily became a wood Macadam, the first failure was from the blocks rotting on the bottom in patches, so that the surface would first be found to be *sheared* down by a heavy load; and on taking out

the blocks they would be found sound on their tops, where the gravel had been driven into them by the traffic, and also a sound film of about the thickness that tar could be expected to penetrate a wet block, the inside being rotten. In other cases, however, when the layer of sand was too thin, the mud worked up through both boards and blocks, reducing everything to about the state of those having no boards under them.

A layer of concrete, covered with Trinidad bitumen, will effectually stop the mud from coming up, and any percolation of the surface water into the soil through the pavement; the narrow joints, by preventing the edges of the blocks burring over, will both tend to keep the surface smooth, lessening the shocks of the wheels, and greatly facilitate all the operations of cleansing. Creosoting, by the preservative and antiseptic properties of the dead oils used in that process, will probably keep the timber from decay, so that nothing but abrasion need be feared, and the sanitary objections to decaying wood will be removed.

The following note of some experiments by E. R. Andrews (published in "Engineering News") shows the efficacy of creosoting for protecting wood from moisture.

The following are the results of some careful experiments with different varieties of wood, half of the specimens being simply dried and the others creosoted, to ascertain to what extent wood is rendered water-proof by creosoting. The specimens were soaked during two days in water, being carefully weighed before and after soaking :

Varieties of Wood.	Percentage of Water absorbed.
Spruce, creosoted	.0236
" "	.0306
" dried only	.1754
" "	.3333
" Burnettized	.2500
Hard pine, creosoted	.0000
" dried only	.1600
Oak, creosoted	0625
" dried only	.2000
White birch, creosoted	.124[illegible]
" dried only	.4300
Cottonwood, creosoted	3470
" dried only	.7140
Black gum, creosoted	.1250
" dried only	1.000
Sesquoia Gigantea (great tree of California), creosoted	.0000
" " " dried only	.4722

In the rooms of this Society are creosoted fir ties from England that have been in the track for 20 years, and apparently justify the assertion of the Engineer sending them, that they are good for 10 years more.

The following extract, from the "Railroad Gazette," is also corroborative :

The German Railroad Union, some time ago made inquiries as to the extent to which processes for preserving ties were employed, and what the results were.

It appears from statistics of German railroads which have used treated ties more or less since 1840, and therefore have had time to test thoroughly the life of the ties, that the average life of ties not treated, and of those treated with chloride of zinc or creosote has been:

	Not treated.	Treated.
Oak ties	13.6 years	19.5 years
Fir ties	7.2 "	14 to 16 "
Pine ties	5.0 "	8 to 10 "
Beach ties	3.0 "	15 to 18 "

The average life of 831,341 pine ties treated in various ways on thirteen German roads was 14 years.

It follows from this that there is an increase in the life of ties treated with chloride of zinc or creosote, amounting to about 40 per cent. for oak, 100 to 130 per cent. for fir, 60 to 100 per cent. for pine, and 400 to 500 per cent. for beech.

It thus appears that there is a great deal gained with any kind of wood, but most with some of those usually not considered good for ties, fir and beech being made almost as durable as oak. Bischoff says that it is of little advantage to secure the ties from decay for longer periods than above stated, as the ties usually become worn out or crushed by that time, even if not decayed.

Commenting on these facts, Bischoff, says that it is now generally admitted that the choice lies between creosote and chloride of zinc; that creosote is the best antiseptic material, but also that it is the dearest.

There can be but little doubt that the antiseptic properties of the creosoting process are of more value than the increased life it would give to the blocks.

On account of the absence of proper stone and the cheapness of wood in large areas of our country, the small first cost of wood pavements seems to make it worth while to give them an intelligent trial.

The thoroughness with which wood pavements can be cleansed depends on the size of the joints and the firmness of their filling. The practice in London, when the mud is at all sticky and not so thick as to require scraping, is to water and then sweep with a revolving broom, the thoroughness of the cleansing being almost directly as the amount of water. In hot weather a disinfectant is sometimes applied after sweeping.

Asphalte and Bitumen.

Dictionary and encyclopedia makers, as well as chemists, seem to use these terms interchangeably. M. Leon Malo, in his "*Guide Pratique pour La Fabrication et L'Application de L'Asphalte et des Bitumes*," after speaking of the lack of definition in the two terms as generally used, gives the following, viz. :

"*Asphalte*, Bituminous Limestone."

"*Bitumen*, The black and viscid substance which we find disseminated in the pores of bituminous limestone and in the interstices of the molasses of Seyssel or the sands of Auvergne."

"*Asphaltic Mastic*, Bituminous limestone transformed by dressing (*cuisson*) and by the addition of a small quantity of bitumen."

He adds: "We employ these definitions throughout this work, and give to them the senses which we have just indicated, and I hope strongly that they will be adopted for use, for they seem to be the most reasonable."

It is believed his definitions have been generally accepted by European technical writers and in specifications relating to the use of these materials,* and the writer in this paper will use them as above defined, excepting that the bitumens from Trinidad and Cuba will be included with those mentioned by M. Malo.

In view of the practice in this country two other definitions seem necessary, viz.:

Bituminous mastics, mixtures of bitumen, either having an earthy *gangue*, like those of Trinidad and Cuba, or purer ones, like Grahamite and Albertite, with limestone or other substances not naturally impregnated, which add to its resistance to wear, and—

Tar Mastic, a mixture in which the bitumen is replaced by (usually) gas tar.

M. Malo further characterizes asphalte as a carbonate of lime perfectly pure (excepting, sometimes, a trace of silica), naturally impregnated with bitumen. Its characteristic color is that of chocolate—which it also resembles in fracture—mean specific gravity 2.235. It is quite hard when cold, and falls to pieces at a heat of about 122°–140° F. At an intermediate temperature it flattens under the blows of a hammer; its structure varies with its locality, but in general should be fine-grained and homogeneous, without particles of unimpregnated stone.

In the poorer qualities the impregnation, though regular, does not exceed 6 per cent., or the bitumen is injected into minute cracks, showing under the microscope that the impregnation is not molecular, or the rock contains *clay*, or, as in the case of Lobsan, the bitumen contains light oils which injure the consistence of the mastic, in which case the light oils are driven off by heat, the remainder being used.

*In Paris, the asphalted sidewalks are universally spoken of as bitumen, in distinction from wheelways, which are called asphalte.

Generally, we may say that the more uniform and microscopic the impregnation of the lime is, and freer from extraneous matters, the better it is.

Neglecting the Tubal Cain stage of its history, asphalte was first applied to sidewalks and wheelways as a mastic, but in that state was not sufficiently resistant for streets of much traffic. It was seen, however, that in summer the pieces of rock that fell from the carts between the mine and the mastic works at Seyssel, compressed under the wheels. In 1849, a Swiss Engineer, M. Mérian, put this lesson to profit, by constructing a Macadam road of asphalte, which was compacted with a roller. In spite of the instability of its foundation and the irregularity of its maintenance, this road is still in very good order. (Malo, p. 108.)

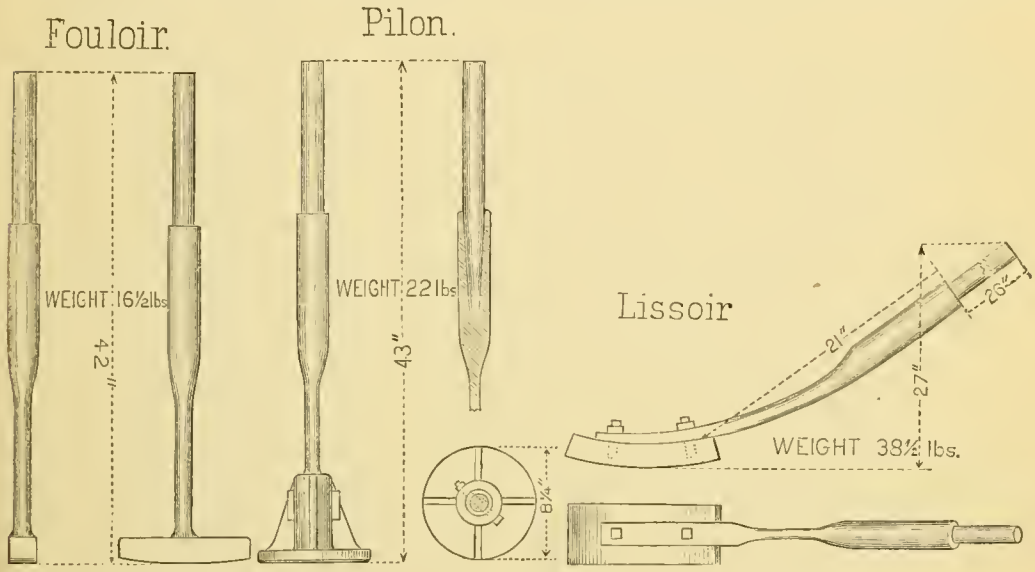
Compressed Asphalte.

The first *compressed asphalte* was laid in Paris by M. Vaudry in 1854, though it was not till 1858 that it was laid on a large scale; the area covered in 1878 by pavements and cross walks was 324 654 square yards, or nearly 14 miles of a street with a 40 feet wheelway. The earlier practice was to "decrepitate" the rock (broken to about the proper size for Macadam) by heating it to about 140° F. in shallow iron pans. Skill was necessary in this operation, as the rock was liable to be burned, *i. e.*, have too much of the bitumen driven off, or to have too little, and sometimes both results were reached in the same batch. The walks in Union Square, N. Y., are an example of the ill effects of unskillful decrepitation.

The rock was also broken up by the direct action of steam, but it was impossible to secure a product of uniform fineness, and difficult to remove all the moisture. After experiments with various machines, a Blake crusher is first used, the pieces are then passed through a Carr's disintegrator, after which the powdered rock is heated in revolving cylinders to from 212° to 284° F. (depending partly on the distance it has to be carried), and transported to the place where it is to be laid, usually in covered sheet-iron wagons.

The permanence of this pavement depends primarily on the stability of its foundation, which is usually of concrete (though old asphalte is sometimes used) 6 inches thick; on this, when it is thoroughly dried, the heated powder is spread, by means of rakes, to such thickness, that when compressed it shall be from 1½ to 2½ inches thick—depending on the probable amount of traffic. The compression, which is termed pilonnage, is effected by the aid of the tools figured. The fouloir is first used

along the junction of the asphalte with either the curb-stone or the paved gutters, while the rest of the surface is compacted by the pilon, beginning with light blows and ending with vigorous ones. All these tools are heated *nearly* red hot, as the powder sticks to them when they are cold. After the surface has been thoroughly compacted it is tested



with a straight-edge, and then rubbed with the lissoir, also heated, giving a glaze to the surface, after which it is dusted over with cement and allowed to cool thoroughly before the traffic is turned on it.

Efforts have been made to secure a more regular surface than is practicable by pilonnage and at less expense by rolling, but it was difficult to so heat the rollers that the powder would not adhere, and the pavement was liable to tear as it was about finished.

The powder retains heat for some time, and the work goes on in a continuous sheet for the day, a gang of ten or twelve men being able to complete about 600 square yards per day. In the morning the uncompressed powder at the edge of the work of the day before is swept away, and hot powder put in its place, which in turn is removed after having heated the old work ; the spreading and pilonnage then goes on as before, leaving small or no trace of the junction.

Great care should be taken that the concrete foundation is thoroughly dry, otherwise the hot powder evolves steam, which permeates the powder and leaves the compressed mass in nodules called *almonds*. These do not show during pilonnage, but are developed by the traffic, when the place is cut out and refilled. A very slight defect seems capable of starting a hole in compressed asphalte, and for the first two

weeks it is under traffic it should be watched closely and repaired promptly. The defects caused by deficient aggregation of the molecules show themselves more readily than those caused by steam. Overheating, which renders the asphalte as inert as sand, is one cause of deficient aggregation, and laying the powder too cold is another.

When the asphalte is too rich in bitumen or the bitumen is too oily, the compressed asphalte forms waves under the traffic, sometimes longitudinal and at others transverse.

So far but few asphaltes have been found that are available for compressed pavements. The Val de Travers (from Neuchatel) was first used, but in 1867 Seyssel (Pyrimont) was used with success in the Rue de Richelieu, and both have since been used by the General Asphalte Company of Paris, which, until January, 1878, laid and maintained the asphalte roads in that city. The Val de Travers asphalte is of the two more regular in its grain and impregnation, and richer in bitumen, having 9 to 13 per cent. Seyssel is not so regular in its grain and impregnation, and contains from 7½ to 10 per cent. of bitumen. The base of both is equally pure carbonate of lime, containing about 2 per cent. as a maximum of silica. Of the two, M. Ernest Chabrier, for a long time manager of the Paris Company, in his paper read before the Institute of Civil Engineers, says: "No Engineer could conscientiously say that the Val de Travers is better than the Seyssel asphalte. The former may be safer in the execution of a work not subjected to supervision; the latter offers greater guarantees of good execution, because more care is required in the work."

It was also held that, for compression at least, the two should not be mixed, and that only pure limestone, impregnated with from 8 to 12 per cent. of bitumen, was available for compression; but within the last two or three years the Limmer & Vorwohle Asphalte Company of London found their mastic pavement breaking up and employed the Sicilian asphalte (which is certified by W. J. Fewtrell, F. R. S., to contain as high as 30 per cent. of bitumen) in compressed pavements and sidewalks. Aldgate and Newgate streets having been laid with this asphalte are apparently wearing well. And in Paris, Paul Crochet, who has the contract for new work and maintenance for five years from 1878 (see Appendix, No. 4) has used, so far, a mixture of Lobsan and Seyssel Forens-Nord. M. Malo says of Lobsan: "It contains within its bitumen an oily substance which renders it too soft and injurious to the consistence of asphaltic mastic; we free it from this oil by distillation, after

which it is in a proper state to be used." The Seyssel Forens is a heavy limestone, very poor in bitumen. As after a careful investigation the Engineers of the Ponts et Chaussées have allowed it to be used in Paris, it seems that, theoretically, at least, a mixture of two dissimilar asphaltes is not disadvantageous, nor is the use of an asphalte that contains a hydrocarbon of the more volatile series; also that, as in the case of the Sicilian, an asphalte containing more than twice as much bitumen as was formerly thought the safe maximum, can be successfully laid under exceptionally heavy traffic.

There was an unwillingness on the part of the manager of the Limmer and Vorwohle Company to explain the manner in which he handled his material, but it is probable that it was skillfully roasted so as to drive off the excess of bitumen as his compressed roadways showed less tendency to roll in hot weather than those laid from Val de Travers rock.

By the kindness of Count Kielmansegge, one of the directors of the Neuchatel Company, I am able to give the following analyses of Val de Travers asphalte. These two sets of analyses by Charles Heisch, F, C. S., were made in consequence of complaints by their customers that the rock was becoming too rich in bitumen :

September, 1876. 5 samples.

Bitumen.....	9.46	9.48	11.98	11.96	10.06
Carbonate of lime,	90.54	90.52	88.02	88.04	89.94
	100.00	100.00	100.00	100.00	100.00
Loss at 212°.....	1.46	1.42	3.04	3.22	1.92

July, 1877. 3 samples.

Bitumen	10.2	11.5	12.32
Carbonate of lime,	89.8	88.5	87.68
	100.0	100.0	100.00
Loss at 212°.....	2.46	2.6	3.2

The loss was moisture and light oils. A small amount of silica was estimated with the lime.

Mr. J. Knight, Secretary Society Francais des Asphaltes, gave me the following analyses made by Steen of Copenhagen :

Seyssel Pyrimont,	Organic,	12.00	Soluble in	ether,	9.62
			Insoluble "	"	2.35
	Inorganic,	88.00	Soluble in	acid,	86.45
			Insoluble "	"	1.55
Seyssel Garde bois,	Organic,	9.70	Soluble in	ether,	9.15
			Insoluble "	"	.55
	Inorganic,	90.30	Soluble in	acid,	85.10
			Insoluble "	"	5.20

The Garde bois asphalte is only used as a mastic, according to Mr. Knight, not having coherence enough for satisfactory compression.

Mr. W. H. Delano, manager of the Compagnie Générale des Asphaltes de France, says of an asphalte for compression that "it should be carbonate of lime (without admixture of foreign material) and mineral bitumen which does not evaporate at 302° F. Some bitumens contain an oil which commences to evaporate at 158° F.; they may, when purged of the light oil, leave an excellent quality behind. The physical qualities of the limestone should also be carefully examined; but whatever the result of even a careful analysis may be, the value of a new asphalte cannot safely be determined except by actual experience extending over three years, at least, of hard winters and hot summers." Col. Haywood also was understood to say that at least three years were necessary to prove the good qualities of a new or untried asphalte. His experience is strongly against any form of asphalte pavement except "compressed."

From a sanitary point of view an asphalte pavement is without a peer; its surface is smooth, regular and non-absorbent, with no cavities or cracks of any kind to retain the infected mud and dust of the streets, and the soil beneath it is kept dry. It is more thoroughly cleaned, either by sweeping or washing, than any other pavement. Its freedom from noise and other excellencies, is fast placing it in all the business and banking streets of the City of London, where it seems to be superceding all other pavements.

In comparison with granite pavements, its great economy is to brain workers and the owners of horses. M. Darcy estimates that the expense of maintaining and renewing horses and carriages in Paris would be reduced one-half if asphalte was substituted for pavement throughout the city.

Its disadvantages are it is expensive; it is not well to lay it on a grade much greater than two per cent.; it is subject to slight decay in the gutters, which they try to correct in Paris by laying the gutters with stone sets; and lastly, the most serious charge, that it is slippery and dangerous to horses. No doubt at the commencemet of a rain, or in foggy weather, its surface is slippery unless it is very clean, and a horse turned suddenly is liable to fall; but when dry or thoroughly wet no such charge can be brought against it.

Referring to Col. Haywood's much quoted tables comparing granite, asphalte and wood we find that before an accident occurs a London horse will travel on granite 132, on asphalte 191 and on wood 446 miles. "That of those accidents which are most obstructive to the traffic, as well as most injurious to the horses, asphalte had the greater proportion, granite the next and wood the least."

He says further in a report upon asphalte and wood pavements:

"*First.*—As regards convenience: That asphalte is the smoothest, driest, cleanest, most pleasing to the eye and the most agreeable pavement for general purposes; but wood is the most quiet.

Second.—As regards cleansing: That wood may be kept cleaner than it hitherto has been, but will be more difficult to cleanse effectually than asphalte. That as both pavements require occasionally strewing with sand or gravel there is no difference between them in that respect.

Third.—As regards construction and repairs: That asphalte and wood, taking all seasons into account, can be laid and repaired with about equal facility; but the smallest, neatest, cleanest and most durable repairs can be made in asphalte.

Fourth.—As regards safety: That, whether considered in reference to the distance that a horse may travel before it meets with an accident, or the nature of the accident, or the facility with which a horse can recover its footing, or the speed at which it is safe to travel, or the gradient at which the material can be laid, wood is superior to asphalte.

Fifth.—As regards durability and cost: That wood pavements, with repairs, have, in this City, had a life varying from six to nineteen years, and that, with repairs, an average life of about ten years may be obtained; that the durability of the asphaltes is not known, but that under the system of maintenance adopted they may last as long as wood; that, contrasting the tenders for laying and maintaining for a term of years the two best pavements of their kinds, wood will be the dearest."

The above remarks refer to London, and inasmuch as our climate is much the driest, and as asphalte is safer where dry, the comparison would be more in favor of asphalte here than there.

Both the compressed and mastic surfaces are easily and thoroughly cleaned by washing and by sweeping when either wet or dry. A *squeegee*, which is a long-handled scraper, with a rubber blade 32 inches long, when pushed along a wet pavement both cleans and dries it.

It may at first sight seem that if a person will indulge in the luxury of changing his gas company on the receipt of each bill he should be

compelled to make good the surface of the street, and the ease or difficulty of making repairs should largely be a consideration for those who open the streets, but as a matter of fact it is almost impossible to properly inspect the work of plumbers, and while one avenue in this city has on its surface a double tracked horse railroad and 240 elevated railroad columns per mile, with one sewer, three water pipes, and eight gas pipes (belonging to four different companies) under it, the subject cannot be without interest. In general, any pavement with a foundation of concrete can be, and probably will be, more thoroughly repaired than one with a loose foundation, such as sand, broken stones, or Telford. For the surface, asphalte is superior to all others in the matter of neatness, Macadam next, and the granite and wood pavements next.

Asphaltic Mastic.

The asphaltic mastic, which is greatly used in Paris for sidewalks, is made, as above defined, from asphalte and bitumen. This bitumen was at first obtained from the asphalte and molasses of Seyssel by boiling either the broken stone or sand (of the molasses) when the bitumen separated, and was skimmed off the surface of the water and sides of the boiler. This bitumen (after being re-melted and allowed to settle to clear it from sand, if necessary) is melted in an iron boiler to the amount of between 5 and 10 per cent. of the required batch, and the powdered asphalte added slowly and stirred in until all is thoroughly incorporated. It is then cast in moulds for sale or use as mastic. When this mastic is used it is necessary to break it up and add it again to melted bitumen, after which 50 to 60 per cent. of fine or coarse silicious sand is added, and the whole kept heated till it does not stick to a clean wooden stirrer.

The mastic is then taken to the place where it is to be laid, in a *locomobile*, essentially a horizontal cylinder on four wheels, with a fire-box under it and an arrangement for stirring the mastic so as thoroughly to mix the gravel and to keep the mixture from burning. It is then laid on a concrete foundation, generally for sidewalks ½ inch thick, or more. It is poured on the concrete from conical sheet-iron pails, and spread by the aid of a wooden hand float. After the spreading is completed, sand, and in some instances gravel the size of peas, is added, and the surface well rubbed. The sand adds to the wear of the sidewalk, and prevents the mastic softening under the heat of the sun. The mastic is sometimes laid in one course and sometimes in two.

M. Malo insists on the bitumen used for mastic, being the same as that impregnating the limestone, but, on account of its scarcity, it has

been almost entirely replaced by refined and tempered Trinidad or other bitumen.

Crude Trinidad contains, besides water, chips, leaves, &c., twenty-five to thirty per cent. of clay, in which state it is brittle, and the clay, as in the case of compressed asphalte, is an element of weakness, as it attracts water. It is refined, according to Malo, "with goudron," a product of a second distillation of schists, which, at a temperature of 59° to 68° F, has the aspect of a completely liquid bitumen; 600 to 700 pounds of this goudron is boiled in a chauldron, into which the crude bitumen, broken to the size of an egg, is thrown in successive doses until the weight is 1 700 to 1 900 pounds. After the ebullition has ceased the fire is drawn and time allowed for the sand and earth to settle, when the purified bitumen is drawn off and strained. The mineral tar of Autun is said to be the best substance now in the market for refining and tempering bitumen.

M. Malo deprecates the use of oils from boghead coal, and petroleums generally. All of the manufacturers interviewed on the subject denied the use of still bottoms or petroleums, and most agreed with Malo that boghead oils should not be used, on account of the cracks which occurred in the mastic; others claimed that the cracks were due either to a poorer quality of asphalte than they used or to an insufficient purification of the Trinidad. See also App. No. 4, art. 17, and App. No. 5, art. 21.

There is a great difference between the true asphaltic mastics, depending on the purity and quality of the asphalte, the purity and component parts of the goudron and the skill of manipulation. A well made mastic is decidedly harder than compressed asphalte, which to a certain extent is partially fluid under pressure, and increases in density under traffic much faster than the surface is abraded. Mastic, on the other hand, as above stated, is hard, crumbling under too great pressure, not noticably compressible, but disintegrating under the blows of horses' feet. It, however, has much more cohesion than compressed asphalte, and should be preferred in those situations where it is not liable to receive the compressive action of heavy loads and is exposed in large areas to changes of temperature; the partial fluidity of asphalte keeps such cracks closed under traffic.

In the courts of the new House of Parliament, eighty by forty-six feet, Claridge's mastic stands without cracks, a beautiful surface: while carefully laid compressed asphalte in the court next to it has cracks in its surface. Claridge's asphaltic mastic, which has a very high reputa-

tion in London, is made from Seyssel asphalte and a very carefully refined Trinidad goudron It is claimed that the Trinidad bitumen, when thoroughly cleared of its clay, has the greatest cohesive strength of any of the bitumens, and the Claridge Company claim that they conduct their refining processes with more skill and thoroughness than any other company. Their mastic is laid in two courses in strips about 3 feet wide, breaking joints.

It is believed that in Paris no compressed asphalte is laid for sidewalks, but in London the Limmer Company is compressing Sicilian on sidewalks, and the Val de Travers Co. always use compressed.

Some mastic was laid in London streets, but it is now being rapidly repaired or renewed with compressed asphalte, except in narrow streets of small traffic, nor is asphaltic mastic laid in the wheelways of Paris.

There is one theoretical point in regard to different asphaltes to which the attention of the Society may be called. That is the fact that some asphaltes will compress and others will only make mastics. The Val de Travers and the Seyssel are very good for either purpose. Lobsan is capable of being compressed, and with proper treatment, making a mastic. Sicilian, as far as known, has only been employed for compression. The asphaltes of Hanover and Brunswick, while they make very good mastics, seem incapable, with the present knowledge, of being compressed, and the writer has met no one who could explain the cause of the differences. It evidently does not lie in the quantity of bitumen contained in the rock, as some Hanover asphaltes contain more than either the Seyssel or the Val de Travers.

Bituminous Mastic.

Bituminous mastics, or the fictitious mastics of Malo and the French writers, were experimented with very generally in Europe, in the hope of finding something as useful as asphalte at a less price ; but it was found that no practicable degree of heat and pressure would give the microscopic impregnation of grain found in the natural mineral.

In this country the effort took a different direction. Refined and properly tempered Trinidad bitumen was mixed with limestone or fine or coarse sand, and a product was sought between asphalte and asphaltic mastic. It is applied neither as a dry powder nor in a fluid or semi-fluid condition, but as a sticky and coherent mass, and is subjected to pilonnage and rolling. While it does not seem to have either the ductility under traffic or the resistance to wear of asphalte, it has less

hard brittleness than the true asphaltic mastic; its great difficulty being a tendency to disintegrate in a rotten manner, possibly from the use of improper oil in refining and tempering the Trinidad bitumen, or else from the inherent difficulty of making an artificial mixture equal in quality to the natural product.

The most successful pavement of this class in this city is the block on Fifth avenue opposite the Worth Monument, laid by the "Grahamite Company." Its component parts are understood to have been a mixture of Trinidad bitumen with fine sea sand containing a little carbonate of lime, and enough Grahamite or Ritchie mineral "to save the patent." This pavement was laid in the spring of 1873, and after the rectification of surface generally necessary, it stood till the fall of '77 without requiring any repairs that could be charged to its own weakness. It was repaired by another company in the fall of 1878, and now requires additional attention. During this time it has filled all the conditions demanded of a good pavement to a greater extent than any other pavement in the city. Three other pieces laid by this company have not proved so successful.

Pavements of this class are very fully described in General Gilmore's Roads, Streets and Pavements.

They are being extensively laid in Washington under a contract for three years' maintenance. As in France and England, it is held that whatever the physical properties and composition of an untried asphalte may be, it is not safe to pronounce it a success until after three years' wear; it seems that a longer maintenance contract would be advisable.

In London, Colonel Haywood, as noticed under the head of Wood Pavements, lets his asphalte pavements at a certain price per square yard for laying, and a provision that they shall be maintained for 2 years at the contractor's expense and 15 years at an agreed price per square yard per annum, and a good pavement be given to the city at the end of the 17 years.

Several different kinds of pavements, compressed and fictitious and other mastics, were laid, the Val de Travers compressed asphalte being the only one that was satisfactory, and most of the other pavements were relaid by that company at the expense of the sureties. The Limmer & Vorwohle Company, however, introduced the use of Sicilian, with which they have relaid Newgate and Aldgate streets, and are relaying Cornhill.

In the City of Jassy, Roumania, the contract (see Appendix No. 5) is based on the London plan. The work was commenced in 1873 and

finished in 1878. It is to be maintained at the contractor's expense until 1880, from that time, and until 1895, at a stipulated price.

In Paris (see Appendix No. 4) the system is to let the construction, maintenance, and repairs of pavements and footpaths for a term of years, 5 to 10, without guarantee of wear, relying on rigorous specifications and thorough inspection for the excellence of the work.

The plan pursued in London and Jassy seems preferable, even with the natural asphaltes, for after the solidity of the foundation is assured, the duration of the wheelway depends so much on the technical skill and thorough honesty exhibited in small details, that the burden of proper inspection should be thrown on the contractor by his having a large pecuniary interest in the soundness of the work done and material furnished. The inspection, however, should be close enough to keep the Engineer in charge fully informed of the methods and materials employed, particularly towards the close of the contract. But no greater injury could be done to a city's system of streets than strictly enforcing the specifications of some of the 300 and more patents taken out for mastic pavements.

The possibility of having any street in continuous good order for 17 years is probably too much for the imagination of the average New Yorker. And no one can well realize the effects of having all the streets so kept in repair.

Tar Mastic.

Among the legacies of the "ring" were the various tar pavements. They were worse than the wood pavements, though not being so thick, they have not proved so enduring a nuisance as the latter.

The best of them are understood to have been made of crude coal tar mixed with gravel and sand, and on the evaporation of the light oils they went to pieces, generally with great celerity. Occasionally a patch would be found that stood the traffic pretty well; this was supposed to result from the evaporation of the oils before mixing with the gravel. G. Leverich, Member of the Society, proposed to secure a uniform product by passing steam of a certain temperature through the tar and driving off all the oils of low specific gravity. Coal tar is now generally reduced to pitch to get the aniline colors, their most valuable product, and the pitch may be tempered by melting with dead oils, a waste product of the distillation. It, however, is very brittle, and it is doubtful if it can be employed economically, except for side-walks of light traffic.

APPENDIX No. 1.

Extract from Specification of W. S. Till, Borough Surveyor, Birmingham, 1877.

The whole of the carriage way to be excavated to the required depth, and the foundations formed to uniform gradients and proper cross sections, with ashes or other approved materials. When these have been rolled and are well set, the contractor to coat the whole width and length of the carriage way with not less than 8 inches of good, strong, clean gravel, screened through a $\frac{3}{4}$ inch riddle, or with not less than 8 inches of approved slag, broken regularly to such a size that the largest piece, on its greatest dimension, will pass through a 3 inch ring.

The gravel or slag to be well gritted and watered, and kept raked together and rolled until the whole is consolidated. * * * * * * *

The contractor to coat the carriage way, throughout its whole length and width, with not less than 6 inches of Rowley Ragstone, broken to pass through a $2\frac{1}{4}$ inch ring.

The stone to be gritted, watered, and kept together, raked and rolled until the whole is consolidated. Crown 6 inches above curbstone. Each layer to be laid on complete throughout the whole length and width of carriage way, and each layer to be separately rolled with a heavy roller.

APPENDIX No. 2.

Extract from Specification for Telford Macadam and Trap Block Gutters on Fifth Avenue.

(4.) Description of Materials.—The stone blocks are to be of durable and uniform quality, each measuring, on the face or upper surface, not less than 4 nor more than 8 inches in length, and not less than 4 nor more than 6 inches in width, and in depth not less than 6 nor more than 8 inches ; blocks of 4 inches in width on their face to be not less than 3 inches in width at the base ; all other blocks in transverse measurement on the base, to be not more than 2 inches less than on the face, but no block on the base shall be of less width or length than 3 inches, and to be in all respects equal to the specimen blocks at the office of the Commissioner of Public Works,

It is also required that the sides of the stones (which form the joints) shall be so sufficiently even and properly shaped that joints may be formed with a similar side not exceeding $\frac{3}{4}$ of an inch, no stone having an objectionable protruding face will be accepted or allowed to be used for paving. They will be carefully inspected after they are brought on the line of the work, and all blocks which, in quality and dimensions, do not conform strictly to these specifications, will be rejected, and must be immediately removed from the line of the work. The contractor will be required to furnish such laborers as may be necessary to aid the inspector in the examination and culling of the blocks ; and in case the contractor shall neglect or refuse so to do, such laborers as in the opinion of the Commissioner of Public Works may be necessary, will be employed by the said Commissioner, and the expense thus incurred by him will be deducted and paid out of any money then due or which may hereafter grow due to the said contractor under this agreement. The blocks must be of trap rock or of syenite, equal in hardness to what is called Quincy granite.

Telford.—The stone for the foundation of the pavement is to be sound hard and durable quarry stone, each from eight to ten inches in depth, from three to six inches in width, and from six to fourteen inches in length, and of a sufficiently uniform size to be acceptable; except the stone under the gutters, which only differ from those above described in that they must be not less than six inches in depth and except the course of stone under the Macadam, which is next to the gutters or the bridge stone, which stone is to be twelve inches in depth, and in every other respect as first above described.

The broken stone for the bottom course is to be of trap rock, and of such size that would pass in any direction through a ring with interior diameter of $2\frac{1}{2}$ inches, and of a sufficiently

uniform size and proper shape to be acceptable, to be composed only of stone that is hard and durable and sufficiently free from screenings and practically free from dirt and other foreign matter. The broken stone composing the next overlying course is to be the same in every respect as just described, except that each stone is to be of such size that would pass in any direction through a ring with interior diameter of 2 inches.

The coarse screenings are to be those of trap rock; the stone is to be practically free from dirt and other foreign matter, to be composed of material only that is hard and durable, no particle of which is to be of larger size in any direction than 1½ inches and all the particles to be of such relative size to 1½ inches as shall be acceptable; through these screenings is to be evenly mixed before rolling a sufficient quantity of the finer screenings of trap rock to form a proper and secure bond.

The fine screenings of trap rock are to be practically free from dirt and other foreign matter, and to be composed of material both as to size and quality that will be acceptable.

(9.) Preparation of Road Bed, &c.—All paving and other stones necessary to be removed shall be taken up and immediately removed from the line of the work; the Belgian and granite blocks to be deposited where directed by the Water Purveyor for the use of the City; the subsoil or other matter (be it earth, rock or other material) shall then be excavated and removed, to such depth to be determined by the engineer in charge, that when rolled and finished, irrespective of the covering of fine screenings, the pavement throughout its entire extent shall be at least sixteen inches thick. Should there be any spongy material or vegetable matter in the bed thus prepared, all such material shall be removed, and the space filled with clean gravel or sand carefully rammed or rolled, so as to make such filling compact and solid. No ploughing will be allowed in preparing the foundation.

The road bed shall be truly shaped and trimmed to the required grade, and with such crown as shall be directed by the said engineer, and rolled with a roller weighing not less than two tons, until the surface is firm and compact.

Laying the Foundation or Pavement.—After the road bed is prepared, agreeably to the terms of this specification and to the satisfaction of the engineer, and the stone hauled and deposited thereon, the foundation stones shall be laid by hand in the form of a close, firm pavement. They shall be set on their broadest edges and lengthwise across the road, except in the case of the stone under the Macadam, which is next to the gutter stones or bridge stones, which foundation stone is to be placed with its longest side parallel to the curb or bridge stone; after being set closely together, they are to be firmly wedged by inserting and driving down, with a bar, in all possible places between them, stones, as near as practicable, of the same depth, until all the stones are bound and clamped in proper position; all the projections and irregularities of the upper part of the pavement shall then be broken off with a hammer, care being taken not to loosen the pavement, and the spalls and chips are to be worked and driven with the hammer into all the interstices not already filled by the process of wedging, so that the pavement, when completed, shall present a sufficiently even surface, and be at each point of such thickness as required by these specifications. No wedging shall be done within twenty-five feet of the face of the work that is being laid, and the stone foundation must be in a compact and satisfactory condition in every respect at the time of the spreading of the broken stone.

Macadamizing.—After the stone foundation has been completed agreeably to these specifications and has passed the inspection of the said engineer, a layer of broken stone of the quality and size herein specified for the bottom course, and of such a depth as will make 4 inches when rolled, shall be spread evenly over the pavement; this layer is then to be rolled until sufficiently compact.

The next overlying course will be of stone, as hereinbefore described for said course, and is to be spread so that the surface will be uniformly 1 inch below the grade and crown when the pavement is finished.

Stone hammers are to be used on this course, so that when rolled as much as shall be required, the surface of each stone that is exposed will not have a longer dimension in any direction than 1 inch.

A layer consisting of the coarse screenings herein specified is then to be applied and spread to such depth as will bring the surface to the proper grade, irrespective of the finish of fine screenings; this layer is then to be rolled, and during the progress of the rolling, if necessary, coarse screenings shall from time to time be applied, so that when the rolling ceases the roadway is truly surfaced to the required grade and crown. This layer is to be rolled until all settlement ceases and the stones are thoroughly compact and the surface true to the grade and crown.

During the process of rolling any course of stone there shall, when required, be spread lightly over the same from a shovel, the fine screenings of trap rock herein described; and after the upper layer has become thoroughly compact, there shall be spread upon the surface fine screenings, so much as to produce a covering half an inch in depth when rolled, and the rolling is to continue until, by a sufficient use of water, a wave is produced before the wheel of the roller.

The rolling of the Macadam stone and screenings shall be done with a roller weighing not less than any of the steam rollers in the possession of the Department of Public Works.

Each layer of broken stone and the screenings or binding material shall be well and thoroughly rolled, and the rolling upon each layer shall be prosecuted until, in the opinion of the engineer, each course shall have been completed, as hereinbefore specified, and until each layer and the finished surface shall be rolled and finished to his entire satisfaction and approval.

While the rolling of each layer of broken stone and the screenings or binding material is being prosecuted the work shall be kept moistened to such extent and in such manner as required, and care shall be taken that too much water is not applied while rolling the first layer, and until after the interstices are well filled with the binding material.

The pavement, when completed, shall be at each point of such construction and at least of such a depth as required by the specifications, and of such crown and such form of gutter as shall be directed, and in any case the thickness of the pavement is to be determined on a line at right angles to the grade and crown.

The use of a proper roller, rammers, or other suitable implement, is to be substituted for that of the steam-roller when necessary.

The construction of the foundation stones, and the Macadam pavement shall proceed so as to be practically equally as far advanced across the entire width of said pavements.

Particular care and attention will be required in obtaining a satisfactory joining of the macadam paving and the blocks in the gutters.

Paving the Gutters.—Upon the stone foundation already described, shall be laid a bed of clean, sharp sand, not too fine, or clean fine gravel, of the depth necessary (about 4 inches), to bring the paving to the proper shape and grade when rammed. The stone blocks are to be laid with joints at right angles to the curb, with joints not exceeding three-quarters of an inch, at such grade and in such form as shall be directed; each course of blocks shall be of a uniform width and depth, and so laid that all longitudinal joints shall be broken by a lap of at least one inch; and the blocks next the curb shall break joints with the curb by at least one inch; as the blocks are laid the joints shall be so filled with sand or gravel as to secure, when the work herein mentioned is completed, against their being any spaces not filled with sand or gravel between the blocks; they shall be covered with clean, sharp sand, which shall be raked until the joints become filled therewith, the blocks shall then be thoroughly rammed to a firm unyielding bed, with a uniform surface to conform to the grade and crown of the avenue, as shall be directed. No ramming shall be done within 25 feet of the face of the work that is being laid; and the ramming is to be done at such times and in such manner with reference to the rolling as shall be directed. When the paving from the centre of an intersecting street to the centre of the next intersecting street is constructed, it shall be covered with a good, sufficient second coat of clean sand, and shall immediately thereafter be thoroughly rammed until the work is made solid and secure, and so on, until the whole of the work embraced in this contract shall have been well and faithfully completed in accordance therewith.

This portion of the work, laid with trap blocks for the gutters, will be measured and included in the returns for Macadam pavement.

No stone or other material, except sand or granite, is to be placed on the blocks that are paved, until these are rammed. When necessary, in order to make good joints, the blocks are to be trimmed down on the sides by and at the expense of the contractor.

APPENDIX No. 3.

ROAD ROLLERS.

As far as known to the writer, the 4 rollers here described are the only ones in the market; they all run with equal facility with either end forward.

THE GELLERAT ROLLER.

These machines (see Plate XXVI), consist essentially of a locomotive boiler, supported on a frame which is carried on two cast-iron rollers, each 3 feet 11 inches in diameter, and 4 feet 7 inches long for the 15-ton rollers, and 4 feet 9 inches in diameter and 6 feet long for the 30 ton rollers. Their peculiarity is that each roller is a driving wheel, and bears half the weight of the machine, which is guided by a hand wheel working from the foot-board into a bevel gear S, Fig. 2, which works the right and left hand screws, *R R*, throwing the axes of the rollers into radial positions; the other, or driving end of each axle, is stationary, with a spherical bearing—*M*, Figs. 1 and 2.

THE LINDELOF ROLLER.

This roller (see Plate XXVII,) has an upright boiler, and two vertical cylinders that actuate a beveled gear which works into a gear bolted onto the driving wheel, the tread of which is a 1 inch plate of wrought iron; the driving roller bears two-thirds of the weight of the machine. Both 10 and 15-ton rollers are built; for the 10 ton, of 2 000 pounds each, the driving roller is 6 feet and the steering roller 5 feet long, giving a weight on the driving roller per inch run of 185 pounds.

THE ROSS ROLLER.

This machine (see Plate XXVIII,) is a combined road roller and rammer. Only one size is built, weighing 44 000 pounds. The boiler is vertical and the rams, any or all of which can be used or not, are actuated by cams. The length of the driving roller is 6 feet in all, with a space in the middle of 8 inches for the driving chain. The steering roller is 30 inches long. Four-fifths of the entire weight is carried by the driving wheel, giving a compressive force per inch run of 550 pounds. It is claimed that the traction is sufficient to allow it to mount grades of 20 feet per 100. Maximum speed, 5 miles per hour.

The rams, five in number, are said to give an effective blow of 7 000 pounds each; they are of no use in compressing and puddling trap, but are efficient with limestone, and must be efficacious for rubble foundations. The frame is utilized as a water tank, and the driving roller can be heated by steam for rolling mastics, &c.

THE AVELING AND PORTER ROLLER.

This roller, which is extensively used in this country, has been improved in several particulars, and is believed to be the only roller now in the market that is run and fired by one man.

As now manufactured (see Plate XXIX), the outside wheels are the driving wheels, the steering wheels covering the space between them. The boiler is horizontal and multitubular; the single steam jacketed cylinder is on top of the boiler, and runs a fly-wheel which by the aid of gearing drives the roller at a speed of about 2 miles per hour. The driving wheels have holes in their treads in which spikes may be placed for tearing up the road bed before remetaling, and the fly-wheel makes the roller available as a stationary engine to run a stone breaker.

Four sizes are manufactured, viz., 8, 10, 15 and 20 tons in weight. Two-thirds of the weight is carried on the driving wheels, which have a width of 2 feet 2 inches for the 20 ton roller, giving a weight per inch run of 574 pounds; the width of driving wheels on the 15 ton roller, is 1 foot 10 inches, giving a weight per inch of 509 pounds. The roller is fitted with a friction brake.

THE GELLERAT ROLLER.

Fig. 1.

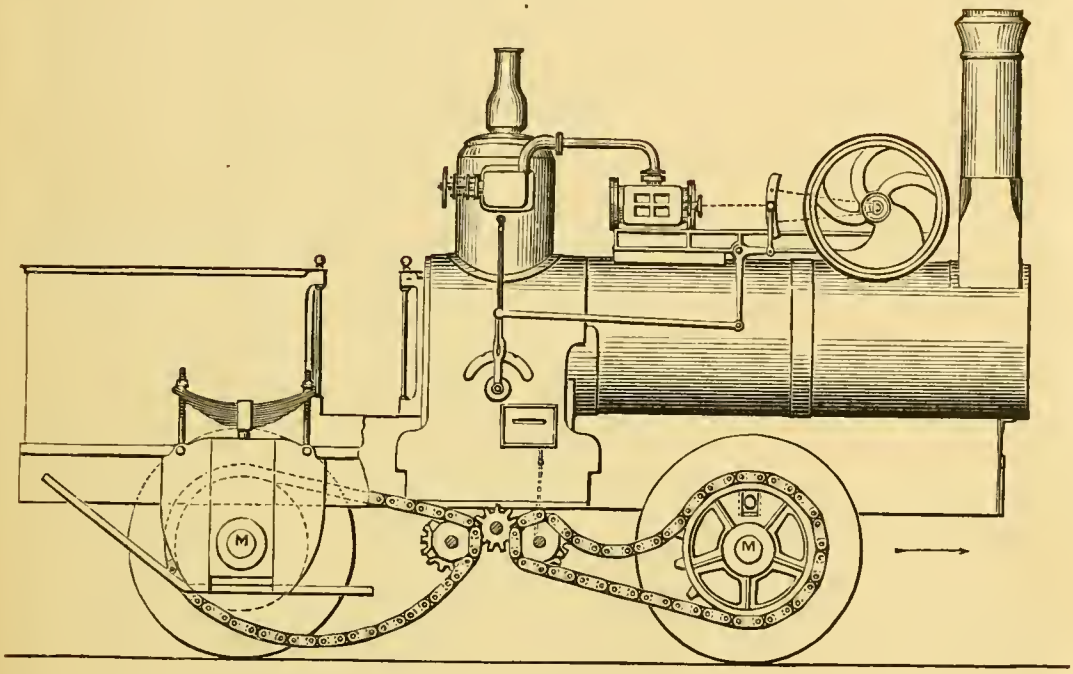


Fig. 2.

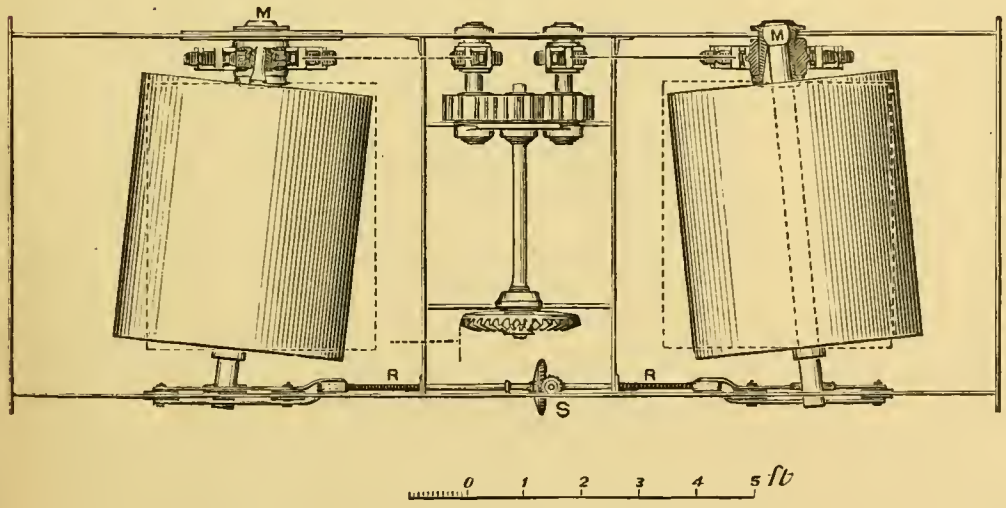


PLATE XXVI.

TRANS. OF AM. SOC. OF CIV. ENGIN'RS.

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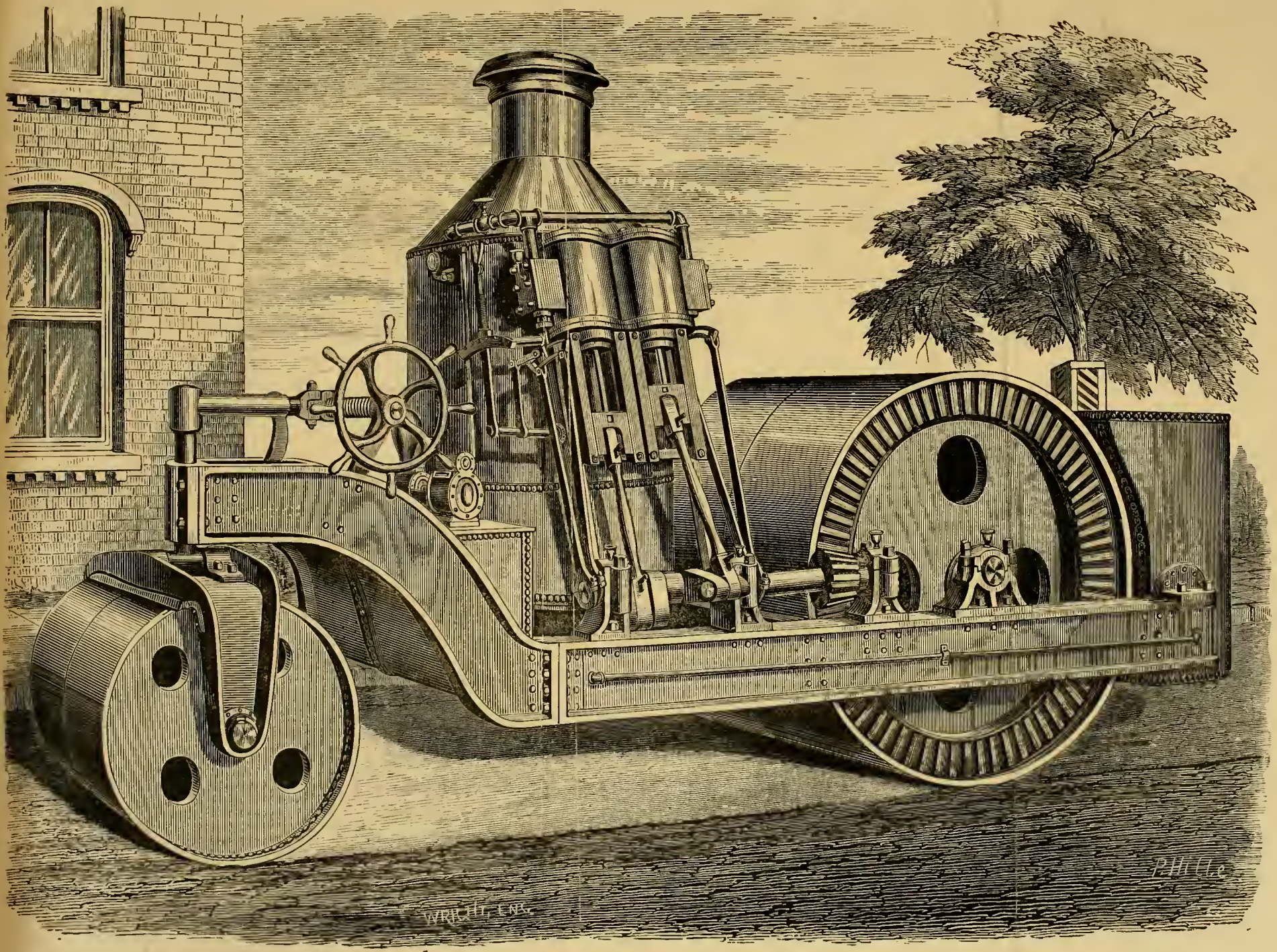
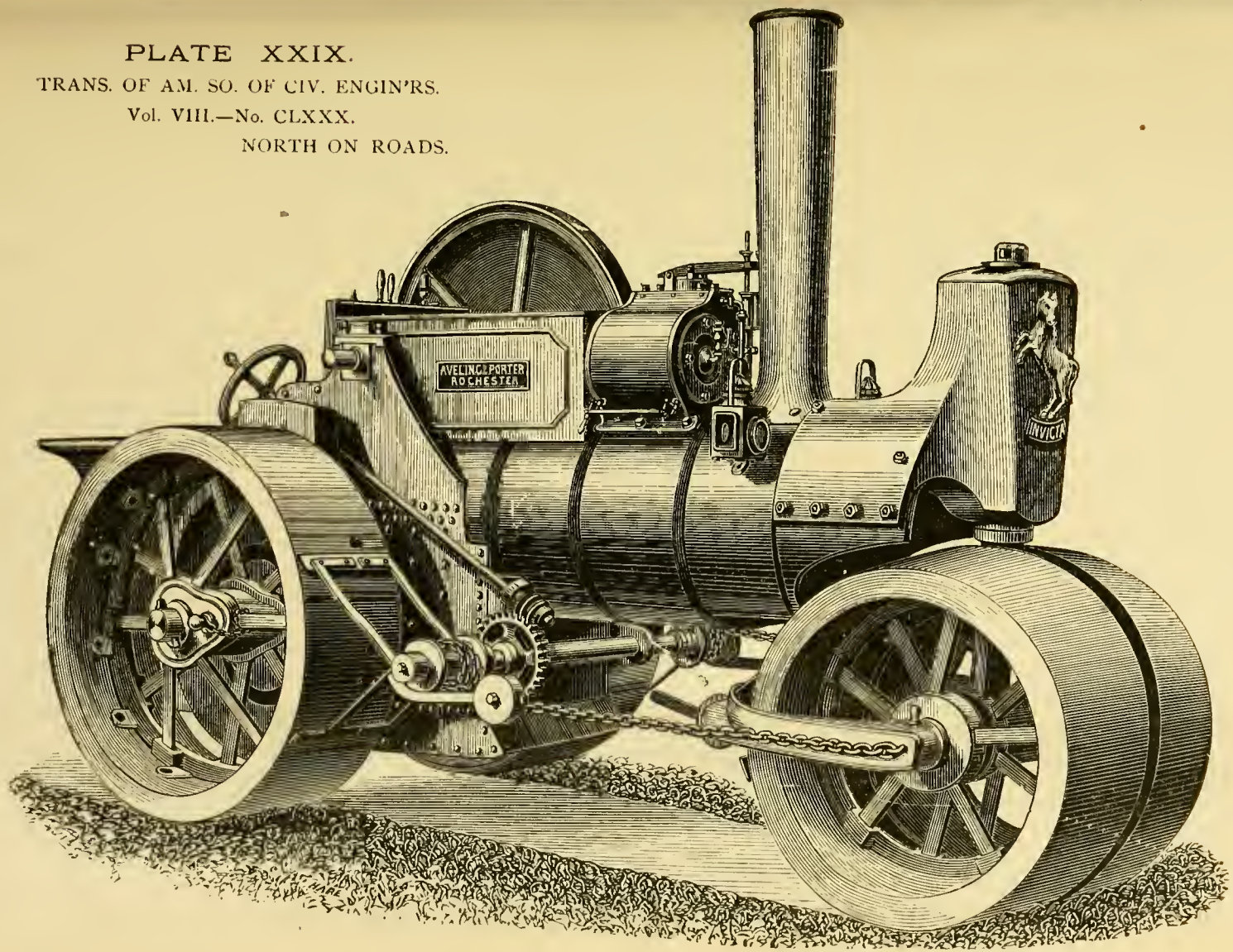
NORTH ON ROADS.

PLATE XXVII.



THE LINDELOF ROLLER.



THE AVELING & PORTER ROLLER.

APPENDIX No. 4.

A part of the Contract for the Construction and Maintenance of the Streets and Sidewalks of the City of Jassy.

Between M. Nicholas Gané, Mayor of Jassy, and Mr. W. O. Callender, of London.

ARTICLE 1. The contract has for its objects :

(*a.*) The construction of a system of streets with gutters and a system of sidewalks with curbs.

(*b.*) The maintenance of the streets and sidewalks constructed under this contract.

ART. 2. The construction consists of the following items of work:

(*a.*) The construction of 47 853.8 square yards of streets, covered with compressed asphalte.

(*b*) The construction of 179 384.3 square yards of sidewalks, covered with asphaltic mastic.

(*g.*) The construction of 17 038.4 square yards of roadway, paved with Macadam made from stone taken from streets now paved.

(*h.*) The construction of 49 210 lin. feet of granite curbing for bordering the asphaltic mastic sidewalks on streets covered with compressed asphalte.

ART. 3. The time fixed for the completion of this contract is five years, to begin with July 1st, 1873, and to end on March 31st, 1878.

ART. 5. The labor of maintenance will consist in maintaining the streets in a constant good condition. On all the streets and sidewalks constructed by him, the contractor will repair, with his own laborers and his own material, all degradations as soon as they appear, and will replace the material lost.

ART. 6. The length of the contract for maintenance is fixed at 15 years, to begin on May 1st, 1880, and to end on April 30th, 1895.

ART. 10. The transverse inclination of the asphalte sidewalks will be 2 per cent.

ART. 11. The curbs of sidewalks of asphalt, on asphalted streets, will be of granite ; those of sidewalks of asphalte, on streets paved with blocks or cobble stones, will be of sandstone, and the curbs of Macadam streets, when they protect sidewalks of the same material, will be of stone cut from the old flagtones of the present sidewalks.

The curbstones will be of the following dimensions: The faces parallel to the surface of the sidewalk will be 5.5 inches in width, of which 0.9 inches of the upper face will be eventually covered with asphalte. They will have a height of 11.9 inches, of which 6 inches will be under ground and the remainder above the gutter ; their length will not be less than 15¾ inches. The form of the curb will be that of a parallelepipedon, having next to the sidewalk a rebate of 0.9 inches in width and a height equat to the thickness of the bed of asphalte.

ART. 14. The gutters of asphalted streets shall have, according to the locality, a maximum width of 3.3 feet ; they shall be constructed of new cobble stones, well culled, or of new sandstone blocks. At the edge of the asphalte there will always be laid a range of granite blocks 10.6 inches in length, 5.3 inches in width, and 9 inches in depth.

ART. 15. The sandstone blocks for the gutters will be dressed to regular cubes in form, of 9 inches on each side.

ART. 16. The asphaltic rock, which must be natural and not artificial, must be from the best asphaltic quarries known: Limmer, in Hanover, Seyssel, in France, and Val-de-Travers, in Switzerland. The asphaltic mastic to be used must satisfy the following conditions:

(*a.*) It must contain 12 parts of bitumen to 88 parts of asphaltic rock.

(*b.*) The asphaltic rock itself must contain at least 7½ per cent. of bitumen, and at the most 93 per cent. of pure carbonate of lime.

(c.) Rocks which contain, even in small proportions, quartz, sulphates, iron pyrites or aluminum must be rejected for the composition of mastic.

ART. 17. The bitumen used for mastic must be natural, not artificial, from the bitumen lakes of the Island of Trinidad, or from the asphaltic rocks of Seyssel, if it is proved to be equal in quality to the Trinidad bitumen: it must be free from water; its specific gravity must be from 1.1 to 1.5. Dipped in water at the freezing point, it must not lose its ductility; its surface must present no cracks or streaks. The surface of a tracture must be black and brilliant. It must be perfectly soluble in petroleum oil or the spirits of turpentine, and the solution when passed through a filter must leave no residue (?)

ART 18. The quarry whence comes the bituminous rock, the mastic and the bitumen must be certified by authentic certificates to be of even fabric and its products of the first quality. Each block of mastic must bear the trade mark of the quarry.

Art. 19. The contractor is forbidden to have in his storehouses any asphaltic rock or mastic which do not comply with the conditions above stated, and not in conformity with the samples deposited with the Mayor on the day of the signing of this contract; he must neither use nor have in his storehouses any bituminous or resinous oils other than those specified in Article 17.

All other material, resinous, bituminous or oleaginous and all other mastic than that like the samples deposited with the Mayor that may be found in the storehouses of the contractor will, on the first offense, be confiscated, and a fine of 1 000 francs be imposed: in case of a repetition of the off use, confiscation and a fine of 5 000 francs; and should it occur a third time, besides the confiscation, the contract will be relet at the expense of the contractor's surety.

Art. 20. The gravel employed in mixing the mastic must be taken from the beds of streams; it must be thoroughly cleansed of all foreign matter, well washed, free from argillaceous matter, and must be passed through a screen, the holes of which do not exceed 0.2 inch.

Art. 21. The sand for making the mortar for beton, and for forming the bed for asphalte, even that employed for bedding the street pavements, the gutters or curbs, shall be sharp, hard to the touch, and will be procured from the best open or working pits, or from the bed of running water.

Art. 22. The cement will be the best from the best known quarries, such as Stefanesti or Rodeni.

Art 23. The stone used in mixing the beton will be broken stone from the quarries of Paun or Barnova. Each piece must pass through a ring of 2.4 inches diameter; it shall be free from all foreign matter and well washed.

Art. 24. The granite shall have the following qualities:

(*a.*) It will be obtained from the hardest seams of the quarries; it shall be homogeneous, sonorous to the blow of a hammer, without flaws or fractures, and free from foreign matter.

(*b.*) It shall have a specific gravity of 2.65.

(*c.*) After an immersion of 24 hours in water, it must not absorb more than $\frac{1}{500}$ of its volume.

(*d.*) When struck a hard blow, it must break in large fragments without leaving any detritus.

Art. 25. The sandstone shall be provided from the hardest beds of the quarries in Roumania. The qualities of the sandstone shall be as follows:

(*a.*) Under the blow of a hammer, the sound of the stone must be limpid and pure; a dull sound would indicate interior fissures, and would be sufficient to reject it.

(*b.*) The specific gravity shall be 2.5.

(*c.*) After an immersion of 24 hours in water, it should not absorb more than $\frac{1}{40}$ of its volume.

Art. 26. The limestone for the beton shall be of the hardest quality, chosen from the hardest beds.

Art. 27. The mortar for the beton of the sidewalks shall be composed of two parts of sand to one part of cement in volume. It shall all be mixed and wet with only as much water as may be absolutely necessary. Mortar which may set before being put in place will be rejected. The composition of the mortar for the beton which is to be used on the streets remains to be described hereafter, as also the compressed asphalte.

Art. 28 The beton will be composed of 3 parts of broken stone to 2 parts of mortar.

The beton which is not used after it is prepared will not be accepted.

The streets which are to be covered with compressed asphalte shall be constructed in the following manner:

(*a.*) The levels will be corrected, the ground shall be shaped to the form of the transverse profile fixed by the City, and will be sprinkled and rolled until it presents a smooth, hard surface.

(*b.*) The curbstones shall then be set, care being taken to cut the joints on the ends as well as on the front edge.

(*c.*) The part corresponding to the gutters will then be made of a bed of sand 2.4 inches in depth, in which will be laid the stones which form the gutters; the sides of the gutters next to the bed of asphalte will in every case have a range of granite blocks. The remainder of the width of the gutters shall be paved with cobble stones, well assorted, in such a manner that the stones will all be of the same size, or with new sandstone blocks, agreeably to the City authorities. The gutters thus laid shall be well rammed with a rammer and over all shall be spread a layer of sand 0.4 inches deep.

(*d.*) That portion of the street which is to be covered with asphalte, will receive a bed of beton, the depth of which, after pilonnage, shall not be less than 6 inches. Upon the beton shall be spread a layer of brick broken to 0.4 inches in size.

(*e.*) On this shall be laid the compressed asphalte, when the foundation shall have reached the the desired consistency and become well dried.

(*f.*) The asphalte will be laid according to the methods usually adopted on works of a similar nature ; the method of doing this remains to be discussed at a future day by the City and the contractor.

ART. 33. The surface of the sidewalks shall be done over when needed, sprinkled and rolled ; over this shall be laid a bed of beton which after compression shall not have a less thickness than 3 inches. On this shall be spread the mastic to a depth of 0.8 inches. This mastic shall be composed of asphaltic mastic, gravel and bitumen in the following proportions: asphaltic mastic 100 parts, gravel 60 to 72 parts, and bitumen 6 to 10 parts. The mastic and bitumen shall be melted in a portable kettle, so that they may be carried to the spot where they are to be used. The mastic shall be broken into small pieces and shall not be poured until it is entirely melted. During the melting the mastic shall be kept stirred, so that a thorough mixture may be ensured and the mastic not allowed to burn. The mastic thus prepared shall be run over the beton in such a manner as to spread evenly over it. Before the complete solidification of the mastic which forms the surface, sand will be spread over it and fixed by light ramming. At the junction between a cold and a hot bed, the edge of the cold one shall be reheated by spreading over it a coating of melted bitumen that will then be removed and the final bed laid.

ART. 34. The tempering of the mastic should be such that it will support, at a temperature of 77 Far., the point of a rectangular pyramid of a height equal to one side of the base, without a depression occurring greater than 0.2 inches under a pressure of 154 lbs. continued for five minutes.

ART. 35. The sidewalks at carriage doorways shall have a foundation of beton 4 inches in depth after ramming, and the bed of mastic will be 1.2 inches.

ART. 37. The junction of the mastic with the walls of the buildings bordering the streets will be made by means of a skirting, that is to say, the plaster will be scraped from the walls of these houses to a height of 2 inches above the level of the sidewalks, and the asphalte will be plastered on the bricks to the thickness of the mortar.

The junction of the stratum of mastic with the posts, curbs, hydrants, and other objects of various natures will be made by heating these objects by a coating of melted asphalte that will be then removed and the final bed laid.

ART. 42. The blocks and the cobble stones that the City authorities may declare unfit for using again will be broken and used as Macadam on streets designated by the City ; they shall be constructed as follows :

(*a.*) The ground shall be well graded, giving it the form and inclination of similar streets.

(*b.*) On the surface thus prepared there shall be laid first, gutters of cobble stones to a width of from 2 5 to 3 3 feet. These shall be laid as specified for streets paved with cobble stones.

(*c.*) On that portion of the ground designed for the roadway there shall be spread a bed of broken stone of 6 to 8 inches, reducing, after wetting and ramming, to 4 to 6 inches in depth.

(*d.*) On this strata of stone there shall be spread a bed of sand, which shall be well wet and rolled, so as to obtain a smooth and uniform surface.

ART. 49. * * * * From the provisional reception, the maintenance of the work completed will be performed by the contractor till April 30th, 1880.

ART. 50. All unexpected degradations, all badly executed work, not only during the progress of construction, but also during the years of maintenance, will be repaired by the contractor, whatever may be the cause of the degradation, and with the least delay, without waiting to be notified by the city, under penalty of a fine of 50 francs for each day of delay after the three first days which follow that of the discovery of the degradation.

Besides that penalty, if the contractor does not proceed immediately to the reparation of these unforeseen accidents, the city shall have the authority to put them in good repairs in his place and at his expense, by deducting the cost from the estimate.

ART. 51. On April 1st, 1878, the city will make a new and minute inspection of all the work done during the five seasons. They will compare the state of the work done with that of each of the estimates made at the end of each season, and if it be found that the works are in compliance with this contract, and in good condition, they will finally accept them and make out a new estimate, of which a duly certified copy will be furnished the contractor.

Art. 52. On May 1st, 1880, the contractor having satisfied the first part of the obligations devolving upon him under this contract, binds himself under a new obligation to the city, that of maintaining for a period of fifteen years, from May 1st, 1880, to April 30th, 1895, the works executed, in consideration of a price agreed upon in advance.

Art. 53. The maintenance consists in repairs, renewals and furnishing materials necessary to the sidewalks, curbs, gutters, &c.; in doing all kinds of work and furnishing materials necessary to at all times maintain the surface of the streets and sidewalks paved by the contractor, in a perfect state of uniformity.

The uniformity of the surface of the streets and sidewalks shall be determined by the use of a templet of iron formed to the normal curve adopted for the surface of the streets and sidewalks. This templet, applied to a street or sidewalk, must not present at any point a swell or depression greater than 0.4 inches.

The surface of the streets and sidewalks shall not show any cracks. The connections with the curbs must be perfect.

Art. 54. Whenever the curbs, the sidewalks, the roadways, the water ways—in a word, everything that goes to make a part of the street, become subject to a displacement or derangement from any cause whatever, the contractor will be obliged to repair them immediately, in conformity to the preceding article. Exception is made, however, to all that applies to the construction or repairs of water or gas mains, which will always be at the expense of the respective grantees.

Art. 55. The contractor shall proceed at once, at his own cost, to repair any degradation whatever, without notification from the city.

Whenever a notification from the city becomes necessary to warn him to proceed with the reparation, the contractor will be liable to a fine of ten francs, and he will be obliged to proceed with the reparation within 24 hours after the receipt of such notification.

If, after that notice, the contractor fails to proceed with the repairs of the degradation indicated by the city, the latter shall proceed with the work; it shall make the reparation, submit the contractor to a fine of fifty francs, and retain the cost of the reparation and fine from any sums that may accrue for the maintenance of the streets, and in case that should not be sufficient, from the sureties.

In case of a repetition of this offense occurring during the course of a single year, the city, besides the right which it always reserves to make the reparation on the account of the contractor, in conformity with the preceding paragraph, will impose on the contractor a fine of 1000 francs.

Finally, on a third infraction in the course of the same year, the city has the right to make, besides the reparations after the rules established above, and of re-letting the work of maintenance to another at the cost of the contractor; if this sale results in a loss to the city, it shall have the right to reimburse itself from the sureties. In case, on the contrary, it results in a profit, the contractor shall have no right to demand it.

Art. 59. The prices for the works executed in conformity to the requirements of this contract shall be:

(*a.*) For compressed asphalte $5.38 per square yard.

(*b.*) For sidewalk asphalted, $2.81 per square yard.

(*c.*) For roadway, with gutters, paved with sandstone blocks taken from streets now paved, $1.94 per square yard.

(*d.*) For roadway or gutters paved with new sandstone blocks furnished by the contractor, $8.41 per square yard.

(*e.*) For roadway, the gutters included, paved with cobble-stones taken from streets now paved in that manner, also for gutters constructed with cobble-stones on Macadamized streets, $1.02 per square yard.

(*f*) For roadway paved with cobble-stones furnished by the contractor, also for gutters paved in this manner on streets covered with compressed asphalte, $1.91 per square yard.

(*g*) For Macadam roadway, $1.45 per square yard.

(*h.*) For granite curb to asphalted sidewalks, $0.95 per lineal foot.

(*i.*) For sandstone curb to asphalted sidewalks, $0.67 per lineal foot.

(*k.*) For curb cut from the old sandstone slabs or flags, $0.39 per lineal foot.

(*l.*) For granite curb used in the edging for asphalte of streets, $0.81 per lineal foot.

Art. 57. The price for maintaining the roadway and sidewalks during 15 years from May 1st, 1880, to April 30th, 1895, shall be calculated from the total area constructed by the contractor, and shall be as follows:

(*a.*) For maintaining compressed asphalte streets with granite curb, $0.09 per square yard per annum.

(*b.*) For maintaining asphalte sidewalk, whatever the kind of curb, $0.04½ per square yard per annum.

(*c.*) For maintaining roadway or gutter paved with old or new stone blocks, $0.29 per square yard per annum.

(*d.*) For maintaining roadway or gutters paved with cobble-stones, $0.09 per square yard per annum.

(*e.*) For maintaining Macadam, including the sidewalks and curbs, $0.15 per square yard per annum.

Art. 58. Payment for work done will be made to the contractor in the following manner; One-quarter of the work done will be paid for in cash, the remainder in City bonds.

The bonds will have 15 years to run; they will bear interest at 6 per cent. per annum, payable semi-aanually; they will be delivered to the contractor at par.

Art. 67. The sums due for the maintenance of streets and sidewalks during the 15 years which follow the construction—from May 1st, 1880, to April 30th, 1895—will be be paid by the City of Jassy, at the end of each month, after deducting all that the contractor owes to the City for repairs made in his name and at his expense, and fines. These payments will be made in cash.

Arts. 69 to 71, inclusive, provide that the contractor shall place a guaranty of 100,000 francs in bonds of Roumania, which may be replaced by bonds of the City. In addition 10 per cent. of the contract price shall be retained, until the sum of 400,000 francs is reached, making a total guaranty of 500,000 francs. This guaranty shall be returned to him as follows: May 1st, 1878, 250,000 francs; and at the end of the years of maintenance, May 1st, 1895, 250,000 francs.

Art. 72. Six months before the expiration of the fifteen years of maintenance, the City authorities will make a general inspection of all the work done and maintained and make an estimate of it.

Art. 73. If during this inspection the City discovers the necessity of any repairs, the contractor shall do the same at his own expense during the following six months, in such a manner that the streets maintained by him shall be turned over to the City in a good condition on the day the contractor completes his contract.

Should the contractor refuse to make these repairs, the city shall proceed to do it at the expense of his warranty.

Art. 74. At the end of the 15 years of maintenance, if the streets are in a good condition, considering only the effects of the weather, but presenting no degradations, the final acceptance of the works will be made and the guaranty deposited by the contractor returned to him.

The coupons of bonds deposited as guaranties are the property of the contractor, who will have the right to collect the sums corresponding to each. The contractor shall also have the right to replace the bonds deposited by him as guaranty whenever they may become extinguished through the process of drawing lots.

Art. 89. The system allowed for the pavement of the carriage ways is that of compressed asphalte. The manufacture of this compressed asphalte will not depart from the rules actually adopted by science and experience, the mode of execution of the compressed asphalte remains to be agreed upon hereafter between the City and the contractor.

APPENDIX No. 5.

Abstract of Specifications and Schedule of prices for the construction and maintenance of foot-paths and sidewalks, in asphaltic mastic, and the Places and roadways in compressed asphalte belonging to Municipal service of Paris, from January 1st, 1878, to December 31st, 1882. Paul Crochet, Contractor.

Article 1. The work has for its object—1st. The maintenance and construction of foot paths and sidewalks in asphaltic mastic, situated in the public ways. 2d. The maintenance and construction of compressed asphalte pavements. 3d. The new works; these works will comprise all the pavements in bitumen and asphalte.

Art. 4. The present letting is made on a scale of prices, and the amount of the work is completely undefined, so that the contractor cannot make any demand on account of any changes that the expenditure may be subject to.

Art. 6. When the adjoining proprietors or other parties in interest have to bear the cost of the works detailed above, or to contribute in any proportion, the contractor will be held to execute the work at the same price as that done at the cost of the City of Paris, and conformably to the orders of the Engineers.

Art. 7. Foot pavements shall have the widths determined by the administration, they shall be composed of pavement in mastic supported on the side of a public road by a curb the height of which shall commonly be of $6\frac{1}{2}$ to 4 inches.

Art. 9. The ordinary curbs in granite shall be $11\frac{3}{4}$ inches wide on top with a total fall across of $\frac{3}{8}$ inch ; 13 inches wide at the base, which shall be horizontal ; $11\frac{3}{8}$ inches high on the front face which shall have a batter of $1\frac{1}{8}$ inches.

Art. 16 The mastic pavements will be formed of a layer of pure asphaltic mastic at least $\frac{9}{10}$ inches thick, resting on a bed of hydraulic concrete 4 inches thick which comprises a covering of hydraulic mortar at least $\frac{3}{4}$ inches thick.

Art. 17. The compressed asphalte pavements will consist of an upper layer of compressed asphalte $1\frac{1}{2}$ to $2\frac{1}{3}$ inches thick, resting on a foundation of hydraulic lime or cement, concrete 4 to 6 inches thick covered as above with mortar or upon an old Macadam roadway picked over and covered with a thin coat of hydraulic mortar.

Art. 21. The asphaltic mastic employed either for new or repairing old paving shall be composed of naturally impregnated rock with natural bitumen of good quality, coming exclusively from mineral rocks.

The fictitious bitumens extracted by the purification of the heavy oils of schists, the distillation of coal, those so-called fatty bitumens and all other analogous products shall be rigorously proscribed.

The rock employed after being reduced to powder will be melted with a sufficient quantity of purified natural bitumen to form a mastic which, when cold, presents a homologous mass slightly elastic, and which does not soften under a hot sun. This mastic shall be moulded into blocks. There may also be used blocks of bituminous mastic with a base of slates manufactured by the process of M. Sebille.

Art. 22. The contractor shall be bound to employ under the orders of the Engineer upon each public way the bituminous mastic above described.

The mastic shall be formed of a mixture of natural bitumen, in the proportion of one-twelfth of its weight at most, and the calcareous asphalte rocks of Seyssel, Seyssel-Forens, Pyrimont or Volants, of Val de Travers or Lobsan, or others deemed equivalents by the Engineers.

The mastic, having a base of slate of M. Sèbille, will be formed of a mixture of bitumen described in Art 23, following, and of powdered red or blue slate of Ardennes, powdered chalk of Mendon or of Nanterre and of silica from the basin of Paris, in the following proportions, by weight:

Refined mineral bitumen	30
Ground slate	35
Powdered chalk	10
Silica, ground and sifted	25
	100

Art. 23. The bitumen shall come as much as possible from the washings of bituminous sandstone or the asphaltic rock of Maestu, and in their default, from the dry pitch of Trinidad, perfectly purified. It ought to be viscid at the ordinary temperature; never brittle or liquid; drawn into threads it should lengthen and only break in very fine points.

Art. 24. The rock employed should be calcareous, soft, with fine grain, texture fairly compact, regularly impregnated with bitumen so as not to show black and white spots; it should be of a brown color; heated to 122 to 140° F. it should soften and break on being torn. Care must be taken for the areas in asphalte to choose only such pieces as are of the most even grain and richest impregnation. The rock of Lobsan, however, should not be employed alone in the asphalte roadways it ought to be mixed with other rocks less fat in proportions, which will be determined by the Engineers according to the composition of the other rocks. It should contain at least 7 per cent of bitumen, and at the most, 93 per cent. of lime ; its change into mastic, must not require more than 9 per cent of bitumen.

Art. 25. The materials entering into the composition of the pavements are the mastics

described in Art. 22, pure gravel grit and natural bitumen to assist the melting. These materials ought to be generally employed in the following proportions, by weight:

Foot pavements with a base of asphalte,	Asphaltic mastic.....	100
	Bitumen.....	6
	Grit.....	60
Foot pavements with a base of slate.....	Asphaltic mastic.....	100
	Bitumen.....	7
	Gravel.....	50

Art. 26. One month before the award of this contract the competitors must deposit at the office of the works in Paris, samples of—1st, A block of the mastic described above; 2d, Specimens of the asphaltic rocks and the natural bitumens they intend to use; 3d, A note indicating the elements of the composition of the mastics and proportions of the various rocks that they intend to employ in the composition of the asphaltic areas.

The blocks and specimens of rocks and bitumen to have the trade-marks of the works from whence they came and the signatures of the competitors.

The neccessary certificate to compete for the contract will not be delivered till after the examination and acceptance by the Engineers of the specimens deposited. During all the term of this contract the contractor can only use materials exactly similar to the specimens deposited.

Art. 27. Provides for continuous inspection of the contractor's works or the right to compel the contractor to manufacture the mastic in the depots belonging to the City.

Art. 31. The lime employed is to be hydraulic lime in powder. It must be brought onto the works in sealed bags, marked with the name of the maker Only the lime and cement designated in the specifications for the construction and repair of sewers will be allowed.

Art. 32. The broken flint must pass through a ring of 2½ inches and be at least $\frac{6}{8}$ inch thick. It must be free from earthy matters and washed clean.

Art. 33. The sand shall be dredged from the Seine and well cleansed from all foreign matter; it shall be screened from all grains larger than $\frac{3}{8}$ inch for the mortars, or $\frac{3}{16}$ inch for grit for the mastic pavements, the grit for this last purpose shall be perfectly washed and dried before use.

Art. 34. The mortar of hydraulic lime shall be composed of 5 parts of sand and 2 parts of lime, by volume, furnished in powder; the mixture shall be directly reduced to a paste by adding the quantity of water exactly required to reduce it to the consistency of plastic clay.

The cement mortar shall be composed of one part of hydraulic cement of Bourgogne or Portland cement of Boulogne and 3 parts of sand; the sand and cement shall be thoroughly mixed before the addition of any water. All mortar which shall have set shall be rejected.

Art. 35. The beton shall be composed, ordinarily, of two parts in volume of mortar and three of stone. The mixture, made either by the rake or cylinder, must be perfectly uniform.

All beton not used at the time of making shall be rejected.

Art. 36. The bed of beton for the foundation of the sidewalks shall be well rammed and compressed, and must at least commence to set and dry before receiving mastic or asphalte. The beton shall, in addition, be covered with a layer of mortar $\frac{3}{8}$ inch thick.

The gravel for foundation shall pass in every direction through a ring 2 inches in diameter. It must be perfectly compressed and sprinkled with lime grout. This foundation shall have commenced to set before the application of the mastic, and shall be covered with a layer of mortar like the beton.

Art. 39. The ground upon which the mastic pavement is to be placed shall always be previously rammed, watered, and crowned with care. When it is thus made solid the contractor shall spread over it the foundation layer, formed according to the orders of the Engineer, either a bed of beton or of sand covered by a layer of mortar, or a bed of sand impregnated with goudron 2¾ inches thick, or any other foundation prescribed by the Engineer.

In all cases the pavement shall not be laid till the foundation has attained the firmness desired, and become quite dry.

The contractor must conform to the following orders for the manufacture of the mastic to be used for pavements.

The mastic shall be prepared and cast in one or more manufactories belonging to the contractor, and which shall always remain open to the inspection of the Engineers and their agents.

The contractor shall, besides, establish in the manaufacturing depots, both of asphalte and mastic, offices exclusively for the agents of the administration set apart for the inspection of

the composition of these materials. These materials shall not be admitted into the works without a carter's delivery note given by the inspector, setting forth that they have been manufactured in accordance with the specifications.

There shall only be allowed in the works blocks of mastic conforming to the samples deposited and accepted before the award and bearing their trade-mark, or the old mastics from the walks and streets of Paris. All other bituminous matters, resinous or fatty, found in the works by the agents of the administration will subject the contractor to a deduction of $100 for each time.

To assure the execution of these conditions the contractor must not have in any manufactory, under the same penalty, any other blocks than those which should be prepared in his works, and the old mastics taken up.

The use of the old mastic is authorized in the works of the city in the proportion of one-half with the new. The pieces of the old sidewalks having been perfectly cleaned with great care, and regenerated by the addition of new purified bitumen and a sufficient quantity of powdered asphalte to render the old mastic, when melted, of the aspect and consistence of the blocks in fusion.

This mastic shall be melted in hermetically closed boilers, on wheels of a model approved by the administration, and arranged so that the material can be conveyed from the factory to the place to be used, ready to be employed.

For melting, the mastic is broken into pieces 4 inches cube, then the bitumen is melted and the mastic added little by little.

The grit must not be thrown into the boiler till the mastic is completely dissolved.

During the whole time of the operation the matter must be stirred up almost constantly, so that the combination shall be well made and the mastic not burned.

The mastic being well melted and perfectly homogeneous, it shall be run out in bands of about 5 feet wide, spread with a wooden float, and leveled with a strike, so as to present neither fissure or joint. The mastic must be perfectly level, and match exactly with the curbs, &c., against which it is laid. For this purpose, the parts of the curbs, flags, &c., which will be in contact with the bitumen, shall be previously warmed and goudroned.

Art. 40. Upon the soil, well shaped and rammed, shall be placed a bed of concrete, covered with a layer of mortar.

The asphaltic rock, conforming to Article 24, broken down or decrepitated by heat, shall be raised to a uniform temperature of from 248° to 266° F. and carried to the place of employment in vehicles that will prevent as much as possible the loss of heat. It must be completely freed from the water it contains. The use of old compressed, taken from old roads, is authorized for mixture with new asphalte, in the proportion of one quarter of old compressed to three quarters of new rock, provided that the old shall be cleansed with great care before grinding and mixing with the new.

Asphalte shall not be put on the concrete foundation until it is perfectly set and dry.

The powder slall be spread with a thickness about two-fifths more than the finished thickness, leveled with great care, shall be rammed at first carefully, then gradually augmenting the force by means of cast-iron pilons, heated to the proper temperature in portable furnaces. In specially exceptional cases, the compression may also, with the written permission of the engineer be accomplished by means of rollers.

In every case, after the pllonnage is finished, the surface shall be smoothed by means of a heated iron (lissoir).

The road shall not be opened to traffic until it is quite cool.

Art. 41. The specifications referring to the construction of roads and footpaths are applicable to the maintenance of the same. The contractor will be entitled to the old material and will make the the repairs in new material or in the mixture specified in Articles 39 and 40.

Art. 43. In conformity with the contract price, stipulated hereafter, diminished by the rebate of the awarded contract, the contractor must make the necessary repairs to all asphaltic mastic footpaths and areas, furnishing the necessary labor and materials, so that they shall be kept in a proper state. He must each year of the duration of the contract completely relay, in new material, at least the fifteenth part of the surfaces of mastic and compressed asphalte. The surfaces in mastic must be properly plane and regular, presenting neither hollows nor projections of more than three-eighths of an inch in a circle whose radius is 3¼ feet These surfaces must be free from fissures.

Art. 45. As the works in asphalte or mastic are received by the Engineers they will pass into the charge of the contractor who will receive for the maintenance the price stipulated,

commencing from the 1st of January next following their acceptance, whatever may be the date of said acceptance.

ART. 46. The contract prices dimined by the rebate of the award are applicable to the entire surfrce occupied by footpaths or comprsssed asphalte, whatever may be their condition.

In the nine last months of the year instalments may be paid on the contract when the Engineers recognize that the conditions have been loyally carried out. The accumulated sums of the these installments must not exceed four-fifths of the amount of the sums which shall be due after the time has expired. The balance of the contract price of the year will be paid in the course of the first quarter of the following year.

ART. 47. The repairs over trenches for sewers, water and gas pipes or other works will be paid for once at the schedule price, but no demand for further payments on account of sinkings or other dilapidations will be entertained, and the surfaces on these trenches must be kept in the same good condition as the others. For the purpose of securing settlement the contractor may keep the trenches repaired with flint (Macadam), not longer than 15 days.

ART. 49. All damages in the bituminous surface, such as fissues or cracks of at least $\frac{1}{16}$ inch in width, or parting from the curbs $\frac{3}{16}$ inch in width, any lifting up or breaking away of the mastic for at least $\frac{3}{16}$ in depth, depression in consequence of settlement of $\frac{3}{8}$ inch at least in depth under the straight edge, $3\frac{1}{4}$ feet long, will subject the contractor to a deduction of 3 francs (53 cents) per day, when the repairs shall not have been done within 48 hours after notice given by the Engineer.

ART 51. During the continuance of frost, and during the first month after the commencement of the thaw, there shall be no repairs to the pavements maintained by the contractor, and the inspection for defects shall be suspended, but the contractor shall fill with sand and gravel any holes in these pavements within 24 hours after notification by the Engineer, under a penalty of 10 francs ($1.93) for each day they remain unfilled. He may also be authorized, in exceptional cases, to fill the holes with broken flint or melted bitumen, but must replace the flint or bitumen with asphalte as soon as the weather permits. It must be so arranged that the main repairs, intended to re-establish the normal outline of the road ways, are effected from May 1st to November 1st.

ART. 57. The contractor shall execute in private houses the junctions rendered necessary by changes in the public way, which will be paid for according to the price of his contract, subject to the rebate when the works are executed on account of the City.

ART. 65. When a workman leaves one of the districts of the works under the Municipal service, he must have a certificate from the contractor showing the cause for which he left.

This certificate shall be submitted at once to the Engineer who shall be at liberty to refuse the right of employing the said workman, without the contractor deriving therefrom any excuse for not furnishing, when requisite, the number of workmen required. In default of a certificate the workman cannot be admitted, except on the written order of the Engineer.

NOTE.—There are 75 articles in this contract, those not given referring to the setting of curbs, &c., transport of materials and the relations between the Engineer and contractor.

SCHEDULE OF THE PRICES FOR THE WORK SPECIFIED ABOVE.

SOTE.—All the prices below comprise the incidental expenses and the profits of the contractor, and are subject to the rebate of the award.

(This contract is let in 3 lots, the rebates are 7 %, 20.2 %, and 14 %, respectively).

DAY WORK.—The day of a workman, cart or machine, shall be 10 hours of effective work in all seasons ; fractions more or less shall be counted by the hour, or $\frac{1}{10}$ of the day.

The night hours shall be paid half as much more as those of the day, excepting watchmen. Night hours will be counted only from 7 P. M. to 5 A. M., in summer, and from 5 P. M. to 7 A. M. in winter. The summer period begins March 1st, and winter November 1st.

1.	A day of	a laborer	.96½
2.	"	an ordinary mason	1.06
3.	"	an asphalte helper, or of a mason's or paver's helper	.87
4.	"	Granite cutter	1.35
5.	"	Sandstone cutters, pavers and Asphalte workers	1.26½
6	"	watchman	.53

7. Night watchman ..... .79
8. Day of one-horse wagon and driver 2.70
9. " two-horse " " 4.05
21. 1 cubic yard of stone broken for concrete 1.22
22. " ground hydraulic cement 5.13
23. " river sand 1.18
24. " pit sand ..... .89
25. " river sand, washed and dried for mastic 1.48
27. 100 pounds of Roman cement ..... .58
28. " Portland cement ..... .67
29. " asphaltic rock ..... .68
30. " mineral goudron, from Lobsan, Bastennes, or other recognized as equivalent to them, and purified Trinidad or Maestu 3.24
49. 1 cubic yard of mortar, composed of 2 parts of ground hydraulic lime and 5 parts of sand 3.10
50. 1 cubic yard of mortar, composed of 1 part of hydraulic cement of Bourgogne, and 3 parts of sand 5.02
51. 1 cubic yard of mortar, composed of 1 part of Portland cement and 3 parts of sand. 6.42
52. 1 cubic yard of concrete, composed of 3 parts of broken stone and 2 parts of mortar (No. 49) 3.03
53. 1 cubic yard of concrete, composed of 3 parts of stone and 2 parts of mortar (No. 50). 3 99
54. " the same, with mortar No. 51 ..... 4.65
55. 100 pounds of natural bituminous mastic in blocks, made from rock of Seysse', or other equivalent, ready to be employed 1.02
60. 100 pounds of compressed asphalte, taken from streets to be repaired, shall be taken by the contractor (without rebate) at ..... .35
61. 1 square yard of old sidewalks in mastic shall be taken by the contractor, without regard to its thickness. and without rebate, at ..... .19
70. Taking up 1 square yard of compressed asphalte, piling the material included.. .014
71. Taking up 1 square yard of mastic sidewalk, with piling the material ..... .003
73. Cleaning and leveling an old Macadam road to secure a surface of mortar for compressed Asphalte, per square yard ..... .10
93. 1 square yard of new natural asphaltic mastic, 0.6 inch thick ..... .53
94. Greater or less value of each $\frac{4}{100}$ of an inch in thickness ..... .045
95. 1 square yard of sidewalk relaid in natural asphaltic mastic, 0.6 inch thick, the old material belonging to contractor ..... .40
96. Greater or less value of each, $\frac{4}{100}$ inch in thickness ..... .025
97. 1 square yard of pavement, 0.6 inch thick, composed of one-half new and one-half old mastic ..... .50
98. 1 square yard of repairs of pavements composed as above ..... .32
99. For each $\frac{4}{100}$ inch in thickness, more or less ..... .02
102. 1 square yard of compressed asphalte 1.6 inches thick, comprising regulating the surface of the ground, but neither excavation, embankment, nor foundation of concrete 1.73
103. For each $\frac{4}{100}$ in thickness, more or less ..... .17
105. 1 square yard repairs of road 1.6 inches thick, the contractor retaining the old material 1.04
106. For each $\frac{4}{100}$ in thickness, more or less ..... .17
108. 1 square yard of foundation for pavement in asphalte or mastic, comprising regulating and ramming the road-bed, but not excavation.
109. 1 square yard concrete of hydraulic cement rammed to 4 inches in thickness, comprising a covering of mortar No. 49 at least $\frac{4}{100}$ inch thick ..... .34
110. 1 square yard concrete of cement No. 53, rammed to 4 inches thick, comprising a covering of mortar No. 50 ..... .46
111. 1 square yard concrete of cement No. 54, rammed 4 inches thick, covered with mortar No. 51 ..... .54
12. 1 square yard on natural soil, with a bed of sand 0.8 inch thick ..... .04
17. Repairs in which all or a part of the old materials are used, will be paid for at three-quarters of the prices above mentioned.

207. 1 square yard of sidewalk, in natural mastic, half an inch thick, comprising a hydraulic lime concrete foundation, 4 inches thick after ramming, with regulating but not excavating ..... .93

208. Note. When the foundation is in cement concrete the price above will be increased by the respective differences between each of the prices of Nos. 110 and 111 and that of 109.

209. 1 square yard of mastic like 207, on the natural ground, covered with a bed of sand 0.8 inch thick ..... .63

210. 1 square yard of mastic like 207, on the natural ground, covered with hydraulic mortar ..... .68

211 Note. When the pavement is one-half new mastic with old material, the prices above will be diminished by ..... .09

212. 1 square yard of compressed asphalte 1.6 inches thick, including a foundation of hydraulic lime concrete, rammed 4 inches thick, including dressing and ramming the soil but not excavation 2.07

213. 1 square yard of compressed, with concrete of cement No. 51 ..... 2.21

Additional price for work executed on embankments more than 1 yard high, or on trenches, whatever may be the thickness of the pavement or concrete.

215. 1 square yard of mastic ..... .22

216. " " compressed ..... .36

217. Maintenance of 1 square yard of sidewalk in asphaltic mastic, in conformity with these specifications, per annum ..... .05

218. The same for roads in compressed asphalte ..... .19

219. Additional price for maintaining cross-walks of compressed asphalte on Macadamized roads, and of gutters bordering them ..... .10

248. For works not mentioned in the present schedule, the prices in the schedules now in force for maintenance of public ways or sewers and water service will be paid: which prices will be subject to the rebate of the present letting.

The illustrations presented with this paper are as follows:

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

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TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CLXXXI.

(Vol. VIII.—June, 1879.)

FLEXURE AND TRANSVERSE RESISTANCE OF BEAMS.

BY CHAS. E. EMERY, Ph. D., Member of the Society.

§ 1. It is well known that materials like cast iron, with an ultimate tensile resistance much less than their ultimate resistance to crushing, show, under transverse strain, reduced to longitudinal strain by the usual formula, much greater tensile strength than when the strains are actually applied in a longitudinal direction.

§ 2. The subject has excited considerable interest for years. It was discussed by this Society in connection with the paper of Mr. L. Nickerson, giving "*A record of experiments showing the character and position of Neutral Axes as seen by polarized light,*" followed by that of Gen. J. D. Barnard on "*Resistance of Beams to Flexure,*"* and articles in relation thereto containing various theories and explanations, have frequently appeared in the technical journals. Cast iron is not now much used in construction, but it is known that there are also great discrepancies in the application of the theory of transverse strain to other materials, particularly particularly wrought iron and steel, so that a re-examination of the subject is considered of practical value and interest.

* LXXXIII., Trans. Am. Soc. Civil Engrs., Vol. III., p. 31, and Paper XCI., p. 123, same Vol.

§ 3. Mr. B. B. Stoney, in his excellent work on "The Theory of Strains," § 130, refers to the subject as follows :

"Mr. Hodgkinson endeavors to explain this discrepancy by a change in the position of the neutral axis as soon as the limit of elastic reaction of the horizontal fibres has been passed, and gives some reasons for this hypothesis in his "*Experimental Researches on the Strength of Cast Iron*," p. 384. This seems a plausible hypothesis, for if the neutral axis of a solid rectangular cast iron girder approach its compressed edge as the weight increases, and after the limit of tensile elasticity has been passed by the fibres along the extended edge, we shall have a larger proportion than one-half the girder subject to tension, and consequently the total horizontal tensile strain may exceed that derived from our theory, which assumes that the neutral axis always passes through the center of gravity of the cross section (68). Mr. Hodgkinson concludes from his experiments that the neutral axis of a retangular girder divides the depth in the proportion of $\frac{1}{5}$ or $\frac{1}{6}$ at the time of fracture—that is, that the compressed section is to the extended section in the inverse proportion of the compressive to the tensile strength of the material."

§ 4. After stating that this view is corroborated by experiments of Duhamel and the elder Barlow, but controverted by Mr. W. H. Barlow, and apparently disproved by his micrometric experiments, as well as the experiments of Sir D. Brewster, with polarized light, Mr. Stoney concludes :

" The whole question, it must be confessed, is one of great difficulty, and may require numerous experiments before it can be satisfactorily solved. One practical inference is, however, of great importance, namely, that *the tearing and crushing strengths of materials derived from experiments on the transverse strength of solid girders are often erroneous*, and have even led astray men of such capacity as Tredgold."

§ 5. The experiments of Mr. W. H. Barlow, referred to, were made with beams $7\frac{1}{2}$ feet long, 6 inches deep, and 2 inches thick, on the sides of which were cast small vertical ribs, spaced one foot apart, and provided with small holes to receive pins on a micrometric apparatus, used to show the elongations and compressions at 9 different positions in the depth of the beam. The published results for the space between the central ribs, though not agreeing precisely among themselves, show clearly that in that case the neutral axis did not shift materially for loads about $\frac{3}{4}$ of those required to break the beam.*

* See papers of Mr. W. H. Barlow, Phil. Trans., 1855, p. 225 ; Ditto, 1857, p. 463.

Mr. W. H. Barlow advanced a theory based on these experiments, that since the horizontal lamina of a beam are attached together by the force of cohesion, there arises a resistance to bending the mass which is in addition to that developed in elongating the fibres.* This theory has probably received the most attention of the many proposed, but it is evident that, at the section of a beam where the moment is a maximum, the shearing or bending strains are zero, and the fibres subjected only to horizontal strain; yet this is the section for which the maximum resistance is determined, and where the discrepancy is the greatest, the actual resistance being often as much as 2 to 2½ times that determined by accepted theories.

§ 6. Mr. Hodgkinson announced his theory in his work on "*The Strength and Properties of Cast Iron*," published in 1846, and three years after, experiments made by him on the direct tensile and compressive resistances of cast iron, with a view of determining the position of the neutral axis under transverse strain, were published in the "*Report of the Commissioners appointed to inquire into the application of Iron to Railway Structures*," of which commission he was a member.

As will be shown hereafter, the results of these experiments are not in conflict with those published by Mr. W. H. Barlow in 1855, if compared within the same limits, but show that the neutral axis must shift during the higher strains, just before rupture, though ordinarily to so slight an extent as to account for a small portion only of the discrepancy.

§ 7. Frequently verbal expressions are heard that of course the neutral axis must shift to produce equilibrium, since the ultimate compressive resistance of cast iron is some six times the tensile resistance. The discussions of the previously mentioned paper of Mr. Nickerson by Gen. Barnard in his paper, and Prof. Wood in connection therewith, indicate this general view. Evidently a higher strain in compression than in tension can be obtained only when the upper and lower sections are inversely proportional to the ultimate resistances, for the reason that the moduli of elasticity in tension and compression are, within certain limits, so nearly the same that the compressive section being connected by the forces of cohesion to the tensile section, cannot move

* This resistance has been compared to that which would be necessary to prevent a number of boards from slipping upon each other when laid together upon end supports and loaded. [See Mr. Nickerson's paper above referred to]. This is not considered a good illustration of Mr. Barlow's theory. Evidently the thinner the boards the less of such resistance would be developed; so for consecutive lamina there would be no such resistance.

through a greater angle, and, therefore, the compressed side of a symmetrical section cannot utilize its surplus strength until the outer fibres in tension actually begin to stretch rapidly preliminary to parting. This explains the value of the Hodgkinson beam section, as with it the neutral axis can shift toward the *tensile* edge to permit the compressed section to move through a sufficient angle to utilize the ultimate resistance of the material. It is evident, therefore, that a beam with a rectangular or other symmetrical section must always fail in tension, though exhibiting much greater resistance than has yet been satisfactorily explained.

§ 8. It is the purpose of the writer to present the results of experiments showing the relation of the longitudinal strains to the corresponding elongations and compressions, between the tensile and compressive limits of rupture; then to show mathematically the relation between the transverse and direct tensile and compressive resistances of the material, and finally to develop and plot the isodynamic curves, and from their relative position show the probability that there is an equalization of strain between the outer fibres and those nearer the neutral axis, so that the latter, at the section of maximum moment, offer more resistance than is due to accepted theory, and the former are correspondingly relieved; which phenomenon, in connection with a slight shifting of the neutral axis, will account for the increased resistance shown by experiment.

§ 9. In this connection it has been thought desirable to collect together in Appendix A a number of formula relating to flexure and transverse resistance, applicable to both solid and skeleton girders, and extend the same in forms convenient for reference during the present investigation, and others having a different bearing, which it is proposed to submit. In these formula the modulus or coefficient of elasticity has been, as is customary, considered uniform, within what are known as elastic limits. This is not exactly the case, but is practically so in most instances, for the same piece of the same material. It is well known that different pieces of similar material may have very different coefficients of elasticity, which fact must be provided for in some forms of construction.

§ 10. Evidently the principles affecting the flexure and rupture of materials under transverse strain depend upon the same principles; and a truly general equation should give accurate results for every

strain within or beyond the elastic limit. Representing the direct elongations of a unit of the material by x' and the corresponding strain or unit force resulting from such elongation by y', a general equation requires the previous determination of the value of $\frac{dy'}{dx'}$, or the rate of strain for different elongations which shall be correct between the tensile or positive and the compressive or negative limits of rupture.

§ 11. All the physical properties of materials are so dependent upon their chemical and molecular structure, that their relations must necessarily be determined by experiment. By noting and tabulating the elongations and corresponding strains, curves may be constructed like those shown in the plate, in which the elongations and compressions are respectively laid off as abscissa to the right and left of a vertical axis, and the corresponding strains or unit forces developed as ordinates above and below a horizontal axis, the origin being designated *O*, in either case. Necessarily for clearness, the scale for the elongations is much more exaggerated than that for the strains. There has been no attempt to make the scales uniform, the object being simply to plot all the results in the most convenient manner on the same cross section paper.

§ 12. Curve 1 is plotted from the results of experiments made by Mr. Hodgkinson in the years 1847–9 on the direct extension and compression of cast iron bars of the grade known as Low Moor No. 2. The bars extended were 50 feet long in connected sections of 10 feet; those compressed were 10 feet long, and secured in a frame to prevent buckling, being jarred occasionally, when under strain, to give them freedom to shorten. Curve 2 was similarly plotted from the average results of similar trials of a number of different kinds of iron, that above mentioned included. All the bars were one inch square.* Curve 3 was plotted from tests made by Capt. T. J. Rodman, U. S. Ordnance, of a specimen of gun iron marked *DO*, of 82 per cent. Greenwood and 18 per cent. Salisbury cast iron, remelted, made preliminary to casting a 15-inch gun. The specimen extended was 30 inches long—that compressed 10 inches long, both being 1.382 inches in diameter.† Curve 4 shows the results of similar tests of another sample of gun iron. Curves 5 and

* See page 59, Appendix Railway Commissioners' Report, previously mentioned.

† Rodman's Report of Experiments on Properties of Metal for Cannon and the qualities of Cannon Powder, 1861.

6 show the results of experiments made in the Stevens Institute laboratory on the properties of Nos. 2 and 4 Salisbury iron.* Curve 7 shows the results of a test made of the extension of a bar of cast iron by Mr. Wm. Kent, M. E.† Curves 8 are examples made autographically by the torsion testing machine of Prof. Thurston, of the Stevens Institute.‡ Curve 9 shows the results of experiments made by Mr. David Kirkaldy on the direct elongation and compression of Swedish Bessemer steel.§ The specimens were 100 inches long, about $2\frac{1}{4}$ inches wide, and from $\frac{1}{8}$ to $\frac{7}{8}$ inch in thickness. The compressed pieces were kept straight by Kirkaldy's trough apparatus and its adjustments. These specimens, with those used in other tests were exhibited at the Centennial Exhibition, and excited great interest.

§ 13. Curves 1, 2 and 3 show at a glance that cast iron obtains its greater ultimate strength in compression, compared with that in tension, simply by increased compression with a nearly constant rate of strain instead of by an increase in the rate of strain.

§ 14 Calling $\frac{dy'}{dx'}$, or the rate of resistance for varying elongations, the *co-efficient of resistance*, this will be proportioned to the modulus or co-efficient of elasticity within the elastic limits, and if constant within such limits as generally assumed would be represented on the diagrams by an inclined straight line for a certain distance above and below the horizontal axis. It will be seen that this is not so in all cases. Curve 3 practically shows this feature, but many others plotted from experiments with similar material do not. Generally in fact the co-efficient of resistance (and elasticity) is less for limited compression than for limited elongations, which is shown clearly by curves 1 and 2, and Capt. Rodman's experiments indicate that the same thing occurs with iron of a higher grade, the compression branch crossing the extension, when both are plotted above the horizontal axis, as was his custom. A specimen of this is shown by curve 4, in respect to which Capt. Rodman calls attention to the fact that with such material under transverse strain the

* Plotted from separate tension and compression curves published in "Railroad Gazette," November, 1877.

† Kent on Strength of Materials, Van Nostrand's Magazine, Jan. 1878.

‡ Trans. Am. Soc. Civil Engrs., LXXVI and LXXXII, Vols. II and III.

§ Kirkaldy's Experimental Inquiry into the Mechanical Properties of Fagestra steel, 1873.

In this connection the writer desires to acknowledge his indebtedness to Acting Prof. Denton for references to valuable works in the library of the Stevens Institute, and transcripts from the records of the laboratory.

neutral axis must first approach the extended, and afterward the compressed edge.*

§ 15. A number of calculations have been made to ascertain the strain on the outer fibres of a beam, on the basis that the strains for different elongations are proportioned to the ordinates of an experimental curve, instead of directly as the elongations, as in the ordinary theory. To accomplish this it has been found most convenient to derive the relations from the curves as plotted, by finding an equation closely adapted to the particular curve shown, thereby obtaining a value for a function of x, which is substituted in the differential equation in place of one of the factors, x; and, after integration, the special values are divided out and the results expressed in terms of the hight of the section, as is usual. The compression branches are so nearly straight lines within the limits due to transverse strain, that they have been so considered; but provision is made for the angle at which such lines meet the extension curves. Portions of the latter are also considered straight lines when the plotted curves warrant. The equations used and calculations in detail are given in Appendix B, § 47 to 51. It is there shown, § 52, that, by the ordinary formulæ, with neutral axis in the center, the strain Y_0 on the outer fibre $= 6\,M \div b\,D^2$, M being the moment; b the breadth and D the total depth of the section.

§ 16. The tensile branch of Curve 1, showing the results of Mr. Hodgkinson's experiments with Low Moor cast iron No. 2, was found, as plotted, to be closely represented by the equation $y = 1.137\,x - .018\,x^2$. The tangent at the origin $\frac{dy}{dx} = 1.137$, but, being evidently less for the compressive branch, the value $g = .967$ was taken directly from the curve and used in the calculations. Evidently in a case of this kind the neutral axis must first shift toward the extended, and afterward toward the compressed edge, and the final result due to considering the ordinates of the experimental curve may not vary greatly from that given by the ordinary

* The value of the curves in showing the physical properties of materials as illustrated by those from the simple torsion apparatus of Prof. Thurston so impressed the writer that in presenting plans for a testing machine of 400 tons capacity to the Government Board in the year 1875, he embodied, as part of the design an autographic apparatus to show the relations of the strains to the direct changes of length of the specimen. The distinguishing features were adopted by the Board for combination with the machine of Albert H. Emery, who obtained the contract, but have only been carried out sufficiently to show the correctness of the main principle. It is hoped that the whole apparatus may yet be constructed with the strength of parts, and in the original simple form proposed by the writer as devices for this purpose are all that are known to be lacking to perfect this remarkable machine.

theory. In this case the value of Y_0 was found equal to $5.202\ M \div b\ D^2$, the co-efficient being nearly 6 as by the ordinary theory. The final shifting of the neutral axis was trifling, the distance from same to outer fibre on the compressive side being .964 of that on the extended side. Yet this is one of the principal experiments made by Hodgkinson to prove his theory that the neutral axis shifts sufficiently to account for this discrepancy. It is expected, however, that further experiments will establish the fact that the curves near the origin have the same inclination for compression as for extension. The long bars experimented with (see § 12) may have buckled sufficiently to make part of the recorded compressions apparent rather than real before full bearing in guides was obtained.

§ 17. The transverse strength of the iron, expressed by a well known formula is $S = \frac{LW}{4bD^2} = 5580$ lbs. By the ordinary formula the strain on the outer fibre, representing the modulus of rupture of the material, would be six times the above, or 33480 lbs., and the consideration of the actual experimental curve in this case, reduces this to $5.202\ S$ or 29027 lbs., whereas the actual ultimate tensile resistance by experiment was found to be only 15458 lbs., or less than one-half as much as shown by the ordinary theory, and more nearly half as much when the actual sequence of strains shown by the experimental curve is considered.

§ 18. By inspection of curve 2 showing the average results obtained by Mr. Hodgkinson from different kinds of iron, it will be seen that it cannot change the general conclusions materially, and as this represents the average of 16 experiments in compression and more in tension with different kinds of cast iron of apparently average quality, it becomes evident that for such material at least, other causes must be sought than the shifting of the neutral axis.

§ 19. For Curve 3, showing the results of experiments made by Capt. Rodman on a sample of gun iron, the formula gives $Y_0 = 3.2922\ M \div b\ D^2$. The value of S for transverse strain in formula in previous section was 5450, so in this case the ordinary formula would give for the ultimate strength of the material ($6 \times 5450 =$) 32 700 lbs., and when the experimental curve is considered, the modified formula gives for the ultimate strength ($3.292 \times 5450 =$) 17 941 lbs. The actual ultimate strength is stated to be 25 627 lbs., or less than given by the ordinary, and more than shown by the modified formula. In this case the neutral

axis shifted so that the depth of the compressed was but (.596 say) six-tenths of the extended section. There are several influences that may have modified the results. In the first place it is practically impossible to obtain the ultimate elongation by experiment, and we have obtained it from the approximate equation stated in § 54 Appendix, which gives the curve shown by the dotted line. Inspection will show, however, that probably no great error could occur in this way, the ultimate tensile resistance at *s*, on curve being fixed by experiment. Again, in making the experiments the strains were released after each additional thousand pounds, in order to ascertain the sets; and it is stated by Capt. Rodman himself, and other experimenters, that the resistance of iron is increased by giving the material an opportunity to rest between the several impositions of a load, the fibres appearing to rearrange themselves according to the new conditions;* so, probably the resistance given for the greater elongations are somewhat higher than would have been obtained had the time in which rupture was obtained been reduced to that probably occupied by the simpler transverse tests with which we have made comparisons.

§ 20. However, duly allowing for both these considerations, it is evident that even for material of this kind, the introduction of the experimental curve, thereby allowing for the shifting of the neutral axis in the formula, will not account for the discrepancy, the results being that, with ordinary cast iron with little extension, the amended formula still gives the ultimate tensile stress higher than it should be, as shown from Hodgkinsons' experiments; while, for gun iron, with very considerable elongation, such formula gives the ultimate stress lower than it should be.

§ 21. Curve 9. referring to Mr. Kirkaldy's tests of Swedish Bessemer steel, shows that the properties of the material are very different from those of cast iron. The curve within the elastic limit forms nearly a right line, in accordance with the ordinarily received opinion that the elongations are proportioned to the strains, and after the elastic limit is passed a nearly uniform, though slightly increasing, resistance is maintained, both in compression and tension, through a comparatively great range. It is interesting, too, to see how nearly alike the mechanical properties of the material are in tension in compression. The two elastic limits are nearly the same, though other experiments show this is affected somewhat by the hardness. For a material so closely fulfilling

* See Capt. Rodman's work, the Railway Commissioner's Report, and Prof. Thurston's papers, previously mentioned.

the requirements of construction and which are in great part assumed in theoretical calculation for all materials, it would naturally be supposed that the ordinary accepted theories of transverse resistance would give results agreeing, approximately at least, with those obtained from direct experiment, but enormous discrepancies are shown of the same nature as those found in the similar investigation with respect to cast iron.

§ 22. The accompanying table is an abstract from the experiments of Mr. Kirkaldy, previously mentioned—the abstract being more complete than necessary for this investigation, on account of the value of the results for reference.

1	Stamp on Specimen.....	1.2	0.9	0.6	0.3
2	Shearing strain per sq. in. Ultimate (Shearing edges hardened).....	lbs. 61 412	79 737	71 648	45 410
3	Thrusting strain per sq. in. Elastic..	62 333	58 666	53 333	41 000
4	Do. Ultimate.	133 333	117 560	105 333	81 760
5	Effects of latter..... (Specimens 4 diameters in length.)	Skewed	Skewed	Skewed	Buckled
6	Pulling stress per sq. inch. Elastic..	62 033	63 066	58 100	43 100
7	Do. Ultimate..	85 200	106 613	102 632	61 312
	Effects of latter.....	Fractured.	Fractured	Fractured	Fractured
8	Transverse stress. Value of $S = \frac{LW}{4bD^2}$..	24 000	31 950	27 840	18 430
9	Corresponding strains on outer fibre by ordinary formula..... ...	144 000	191 700	167 040	110 980
10	Effects when experiment was stopped.	Fractured.	Fractured	Uncracked	Uncracked

These experiments were made with specimens of bars similarly hammered to two inches square. They were of different degrees of hardness—those at the left being the hardest. Shorter specimens gave higher resistances to compression, and longer ones lower resistances than those stated. Each column of results are the averages from three experiments.

§ 23. For this investigation, we have but to compare lines 7 and 9, which should agree, at least approximately, whereas it is seen that even with this superior material, the ultimate tensile resistance, calculated by the usual formula from the transverse resistance, gives results 70 and 80 per cent. in excess of the actual ultimate tensile resistances for the two harder grades of steel that were broken, and this discrepancy had reached

60 and 80 per cent. respectively, for the two specimens removed before breaking and would have been much greater, evidently, if such experiments could have been continued to rupture. It is stated that the bars of the last series were so soft as to readily permit bending in the form of a horseshoe. The limits of elasticity in tension and compression are so nearly alike,—sometimes the tensile, at others the compressive limit, being a little the higher, that the discrepancy cannot be in general attributed to the shifting of the neutral axis, although Mr. Kirkaldy, by noting the change of shape of circles on the bars, concluded that the axis by no means remained in the center of the bar. Evidently the ordinary theory does not apply either to cast iron or steel even when the latter is soft, and reasons other than those previously stated must be found to account for the discrepancy.

§ 24. During the progress of this investigation it occurred to the writer that an explanation might be suggested by ascertaining the isodynamic curves (or curves of equal strain) in accordance with theory, and plotting them in the same relative positions that they would occur longitudinally in a strained beam. Since a curve from an equation of the form $y = ax^n$ can be passed through any three points of any curve, for simplicity this form has been adopted in determining the equation of the isodynamic curve in Appendix B, § 57, and it has been found to apply about as well to the tensile branch of curve 1 as the more elaborate equation previously used. This equation reduces evidently to the ordinary form when $n = 1$.

§ 25. It is shown in Appendix B, § 61, that the ordinates of the isodynamic curve in terms of the depth of the section on one side of the neutral axis are, for a function in the form above stated, inversely proportional to the *nth* root of the moment. Figure 2 (on the plate) is intended to represent the side of a half beam loaded with a weight W in the centre, and supported at the ends ; and upon the same are plotted a series of isodynamic curves determined from equation (60) Appendix B, on the basis that the exponent $n = .79$, which was found applicable for the experiments with Low Moor iron, as explained in § 57 Appendix. It is suggested as highly probable, in fact almost a necessary inference, that on account of the lateral adhesion of the particles the strains of greater intensity near the top and bottom, and at the center of the beam, are in part transferred to the lamina of less strain in the direction of the curve nearer the axis, so that the fibres crossing the central section of maximum

moment are under greater strain than their proportional distance from the axis, and the outer fibres thereby correspondingly relieved.

§ 26. The action may be illustrated as follows: If strain be applied to the center of opposite sides of a piece of rubber the entire central section of the rubber between the points of application of the force will be strained; the strain being greatest in a line joining the forces, and reduced on either side. If, now, forces of less intensity be applied either side of the first force, the effect will be to increase all the strains somewhat, but a portion of the strain from the original force will still be carried by parts of the section not directly in line therewith, and the fibres directly in line be thereby correspondingly relieved. The question at once arises, how room can be found for increased elongations and compressions necessary to produce increased strains, between the neutral axis and outer edge of a beam? This is evidently provided by the shape of the isodynamic curves which run from the intermediate spaces either side of the axis to intermediate distances in the length of the beam, so an action of the kind mentioned should simply cause the beam to bend more either side of the centre than theory demands, which furnishes the basis, with sufficient delicate apparatus, of experimentally testing the correctness of the hypothesis.

§ 27. In support of this theory, attention is called to the fact that the shorter central isodynamic curves closely resemble the wedge shaped piece excluded when the material parts in compression, showing a concentration of force along the general direction of the curves. Again, curiously it appears from Mr. Nickerson's experiments with polarized light, previously mentioned, that the lines of strain in glass resemble the isodynamic curves presented very closely, and it having been shown that steel, even when soft, presents the same discrepancies of theory with experiment, for transverse strains, as cast iron, it appears probable that it is a general phenomenon for most or all materials, which has not been pointed out from the want of experiments as carefully conducted as those to which reference is made. Lastly, for the surplus strength shown by the very soft specimens of steel which bent very much before breaking this theory in connection with the results of longitudinal tests will account very satisfactorily; for by inspection of curve 9 it becomes evident that after the elastic limit of the outer fibres and many of the intermediate fibres is passed, such fibres are still offering a nearly constant resistance due to the horizontal part of the curve,

while the equalization of strain can still go on as before. The effect of an equalization of strain between the outer and medial fibres is to give the real isodynamic curves greater inclination from the horizontal than those derived from direct longitudinal experiments. From this it appears that the increased strains due to the diagonal direction of the curves may become so important that the fibres will part at one side of the section of maximum moment as is frequently reported.

§ 28. In investigating the general subject, the writer has not thought it proper to pass lightly over this problem which has remained unsolved for forty years or more since attention was first called to it, and although another theory is the final result, evidently a plausible hypothesis must always precede and point out the direction of experiments; and in any event the amount of information necessarily collected to investigate the matter will, it is hoped, interest others in the subject. Moreover, the investigation leads, it will be shown, to formula accurate in form and including probably all the principles involved, but which, if proved to be empirical by the further experiments suggested, will yet serve all practical requirements.

§ 29. As it has been thought better to separate the mathematical part of this paper in an appendix, a brief recapitulation may be of interest.

For a beam subject to transverse strain the moments of resistance of fibres at different distances from the neutral axis are generally calculated by a method due to Navier, based on the suppositions—1st, that the strains are proportioned to the elongations; and, 2d, that the elongations are proportioned to the distances of the fibres from the neutral axis. Thus if the distances last mentioned be represented by the variable x, this quantity finally becomes involved three times in the resulting expression, viz., once to represent the depth of the section (being advanced during integration from its differential, representing the depth of a fibre); once to represent the elongations, or the corresponding strains or unit forces due thereto, and again to give the moment of resistance of each fibre from the neutral axis; such moment assisting in balancing the external moment. It being known that the first of the principal suppositions is not in general true,—that is, that the strains are not proportioned to the elongations, at least for all values to the point of rupture,—it has been suggested that if the true relations between the same were included in the discussion, the well known discrepancies would disappear. Such relations have been included in the formula in this paper, by sub-

stituting for one of the factors, x, a function of x, showing the relations between the elongations and corresponding strains as determined by experiments (see § 15 and § 47), but it is found that by this means the discrepancies are only partially accounted for (§ 16, §§ 53–55).

The writer claims in this paper that the second supposition upon which the formula of Navier is founded, viz., that the elongations of the fibres are proportioned to their respective distances from the neutral axis is also incorrect, and that when the lateral adhesion of the fibres is considered, the positions of the isodynamic curves indicate both the possibility and probability that the intermediate fibres between the axis and outer boundaries of the beam may, and do receive more strain than that due to their positions, thereby relieving the outer fibres (§§ 24–27). This phenomenon can only account for somewhat less than 50 per cent. of the excess of resistance found by experiment (see § 38), and when the excess is greater than this, it is evidently due to the shifting of the neutral axis, which is provided for in the first branch of the inquiry.

§ 30. Equations (51) and (52) Appendix show that, both by the ordinary method and when the shifting of the neutral axis is considered, the strain on the outer fibre is expressed by an equation in the form

(61.) $Y = \frac{KM}{bD^2}$, K as shown in §§ 52–55, § 16 and § 19, reducing to a numerical co-efficient. The portion of the second term $\frac{M}{bD^2}$ will be recognized as equal to S in the well known formula for transverse strain,

(62.) $S = \frac{LW}{4\,bD^2}$ so from (61) we have

(63.) $Y = KS$.

When the function of x representing the relation of the strains to the elongations is in the form (53) $y = \varphi\,(x) = \alpha\,x^n$, and the neutral axis is considered to be in the centre, by combining (56), (20) and (62) we may have

(64.) $Y = 2\,(n + 2)\,\frac{M}{bD^2} = 2\,(n + 2)\,S$, so when Y and S are known, a value of α may be obtained, which in an equation of the form of (53) will give the actual relative strains on each fibre, with the equalization of strains between different fibres duly considered.

With materials for which the ultimate resistance is greater for compression than for tension, a modification of eq. (51) may be used to provide for the shifting of the neutral axis.

§ 31. In practice Eq. (63) may be treated as an empirical formula in which by ordinary theory, as shown by § 52, K equals 6, but when the other conditions herein mentioned are considered, is reduced to from 2.8 to 3.0 for ordinary cast iron ; to about 4.7 for gun iron, and to 3.3 to 3.6 for moderately low steel from the hammer—not annealed or tempered. It is probable that the value for wrought iron is about the same as the latter. These values of K may be made more definite if members will be kind enough to report the results of experiments made by them on both the ultimate longitudinal and transverse resistances of materials of stated kinds and grades.

§ 32. Evidently for solid beams the equalization of strain referred to must commence as soon as flexure begins, which explains the fact that the ordinary formulæ are incorrect, even within the limits of elasticity. When experiments can be directed in the special direction desired, the formula for deflection may be put in a form similar to those developed for rupture in Appendix B. Considerable might be done in that direction with facts available, but will not now be attempted as the formula in Appendix A, based on the ordinary theory (see § 9), can be modified to answer all purposes in relation to skeleton girders which are more generally applicable in large structures.

APPENDIX A.

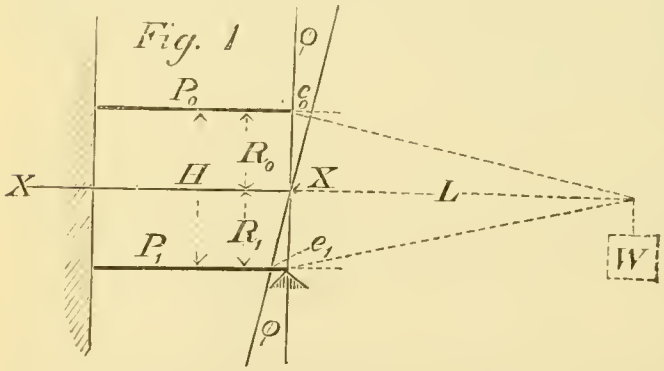
DEVELOPMENT OF FORMULA RELATING TO THE FLEXURE AND TRANSVERSE RESISTANCES OF MATERIALS.

§ 33. If a force, T, be applied to elongate a bar with a section, a, the strain, f', per unit of section $= T \div a$. If $P =$ the original length of the bar, $e =$ elongation under strain, and E the modulus of elasticity, or the force required per unit of section to make the elongation equal to the original length of the bar—on the basis that the strains per unit of section are proportioned to the elongations, which has been found practically true for some materials within the elastic limit by experiment, we have

$$\frac{T}{a} : \frac{E}{1} :: e : P$$

$$(1.)\ \frac{T}{a} = f' = \frac{E\,e}{P} \quad (2.)\ e = \frac{T\,P}{a\,E} \quad (3.)\ T = \frac{a\,e\,E}{P}$$

§ 34. In figure 1 let XX represent the neutral axis of a girder. Distinguish symbols referring respectively to quantities above and below the neutral axis by the indices sub.$_0$ and sub.$_1$, and general quantities applicable to either or both sides of the axis by the same symbols without an index. Let $P_0\,P_1$ represent the full lengths or other portions of the chords of a skeleton girder subjected to longitudinal strains in resisting an external moment (for instance $L\,W =$) M. Let R'^0 and R'_1 equal the distances from the neutral axis to the centers of the chords; a'_0 and a'_1 the areas of the chords; E_0 and E_1 the moduli of elasticity, and e_0 and e_1 the elongations of the chords; N the horizontal strain on chords, and H the effective height of girder, or the distance to the center of the chords when connected by joints; then



$$(4.)\ H = R'_0 + R'_1 \quad (5.)\ N = \frac{M}{R'_0 + R'_2} = \frac{M}{H}$$

As one chord is lengthened and the other shortened a vertical section (at the right, per sketch) will move through a small angle, which represent by φ; the elongation of the chords will then be $\varphi\,R'_0$ and $\varphi\,R'_1$; and from (2) we have

$$(6.)\ e_0 = \varphi R'_0 = \frac{N P_0}{a'_0 E_0} \quad (7.)\ e_1 = \varphi R'_1 = \frac{N P_1}{a'_1 E_1}$$

Combining both equations with (5):

$$(8.)\ M = \frac{E_0 \varphi}{P_0} a'_0 R'_0 (R'_0 + R'_1) = \frac{E_1 \varphi}{P_1} a'_1 R'_1 (R'_0 + R'_1)$$

§ 35. If $f =$ the force per unit of area or the unit force acting at the distance c from the neutral axis the extension due to this force $= c\,\varphi$. Substituting this as the value of e in (1) we have

$$(9.)\ \frac{f}{c} = \frac{E\varphi}{P}$$

When the chords are considered bent at every section the value of P above becomes dx, the distance between consecutive sections, and as φ and P are proportional, in such case we should substitute $\frac{E\,d\varphi}{dx}$ for $\frac{E\varphi}{P}$ As the angle φ is small it may be put equal to its tangent $\frac{dy}{dx}$ so $\frac{E\,d\varphi}{dx} = E\frac{d^2y}{dx^2}$. We may then use interchangeably, in all values of the external moment M, a factor:

$$\begin{array}{ccccccc} & (10) & & (11) & & (12) & & (13) \\ G = & \frac{f}{c} & \text{or} & \frac{E\varphi}{P} & \text{or} & \frac{E\,d\varphi}{dx} & \text{or} & E\frac{d^2y}{dx^2} \end{array}$$

according to the conditions of the problem or the purposes to which the equations are to be applied.

§ 36. Equation (8) may then be put in the following form :

(14.) $M = G_0 a'_0 R'_0 (R'_0 + R'_1) = G_1 a'_1 R'_1 (R'_0 + R'_1)$, and when the length sections and elasticity of the chords are equal, $R'_0 = R'_1$, and putting $2a' = A'$.

$$(15.)\quad M = G(2a'R'^2) = GA'R'^2 = G\frac{a'H^2}{2}$$

If $u =$ the elongation of a chord we may have first, from (2), for either chord, and second, from (2) and (5), when the values of E and R' for both chords are considered equal,

$$(15a)\ u = \frac{NP}{a'E} \qquad (15b)\ u = \frac{MP}{a'EH}$$

$$(15c)\ du = \frac{N}{a'E}dx \qquad (15b)\ du = \frac{M}{a'EH}dx = \frac{M}{A'ER'}dx$$

$$(15e)\ M = a'EH\frac{du}{dx} = A'ER'\frac{du}{dx}$$

From § 34, $u = \varphi R'$, which substituted in (15e) with value of G from (12), gives (15), which, as will be seen hereafter, is equivalent to (23).

§ 37. In applying transverse strain to a solid beam, it is évident that the portions of the section above and below the neutral axis perform the same offices as the chords in the previous discussion. Conceive the

beam made up of an infinite number of longitudinal fibres, and let b represent the breadth and dv the thickness of a fibre, at a distance v from the neutral axis. Under the influence of the moment, consecutive vertical sections, parallel before flexure of the beam, will, by extension and compression of the fibres, move through a slight angle, which put equal $d\varphi$. Maxing x = original length of the neutral axis, when the deflection is small, the projected length will remain practically the same; and as flexure takes place at every section, the length considered $= dx$, the distance between consecutive sections. The elongation of a fibre at a distance v from the neutral axis equals then $v d\varphi$. The force due to this elongation may be found from (3), and is an increment of the total force due to the change of length of all the fibres on one side of the neutral axis; hence,

(16.) $N = E\frac{d\varphi}{dx}\int b\, v\, dv$, so putting h_0 h_1, equal to the distances of the outer fibres from the neutral axis, and using coefficient G from (12), we have,

$$(17.)\quad N = G_0\int_0^{h_0} b_0\, v\, dv = G_1\int_{h_1}^{0} b_1\, v\, dv = G_0\frac{b_0 h_0^{\,2}}{2} = G_1\frac{b_1 h_1^{\,2}}{2}$$

the latter values applying only when b_0 and b_1 are respectively constant.

§ 38. Putting r_0 and r_1 = *radii of effect*, or distances from neutral axis to the centres of effort of all the forces for the extended and compressed sections respectively, evidently the moment of the total force N into these *radii* respectively equals the sums of the moments of the forces due to the changes in length of the several fibres on the corresponding sides of the neutral axis into their several distances from the axis. Hence multiplying each of the above forces by v, we have,

$$(18.)\quad Nr_0 = G_0\int_0^{h_0} b_0\, v^2\, dv = G_0\, b_0\frac{h_0^{\,3}}{3}$$

$$(19.)\quad Nr_1 = G_1\int_{h}^{0_1} b_1\, v^2\, dv = G_1\, b_1\frac{h_1^{\,3}}{3}$$

the latter values applying as before, only when b_0 and b_1 are respectively constant. The integrals respectively represent the moments of inertia of the extended and compressed sections, and will be distinguished by the symbols I_0 and I_1.

[Note referred to in § 29.] If by any means the resisting unit forces could be made the same at all distances from the axis one value of v, above, would be constant, making the denominators in second terms 2 instead of 3, so the aggregate resistances would be increased in the proportion of $\frac{1}{3}$ to $\frac{1}{2}$, or 50 per cent.

§ 39. The effective height H of a solid girder is $r_0 + r_1$, the distance between the centres of effort of the tensile and compressive forces; hence,

(20.) $M = N(r_0 + r_1)$ and adding equations (18) and (19), using value of G from (10) we obtain the somewhat more familiar form.*

$$(21.)\ M = \frac{f_0}{c}\int_{o}^{h_0} b_0\, v^2\, dv + \frac{f_1}{c}\int_{h_1}^{o} b_1\, v^2\, dv.$$

§ 40. On the basis that the moduli of elasticity are alike in tension and compression, taking value of G from (12) and integrating together the expressions for the upper and lower sections another form is obtained viz: †

$$(22.)\ M = \frac{E\, d\varphi}{dx}\int_{-h=h_1}^{+h=h_0} bv^2\, dv$$

The integral in this case is the moment of inertia of the entire section of the beam, and is designated I. Substituting the value of G from (13) in the last equation we have

(23.) $M = E\, I \dfrac{d^2y}{dx^2}$ which is the well known equation of the elastic line. Integrating once gives the tangent of the angle of curvature due to the deflection, and a second integration the deflection itself. The angle and deflection at any point of a girder may therefore always be determined when an expression can be found for the moment.

§ 41. Equations (15), (21) and (22) show that the resistance offered by the extension of each of a series of bars or fibres at different distances from the neutral axis is proportioned to its section into the square of its distance from the axis. By dividing the moment of inertia I_0 of the extended section by the area a_0 of the latter, the quotient represents the square of the distance from the neutral axis at which that area must be concentrated to have the same moment of resistance as when distributed in the actual section. Let this distance, called the *radius of gyration* be represented by R_0, then

$$(24).\ \frac{I_0}{a_0} = R_0^{\,2} \quad (25.)\ R_0 = \sqrt{\frac{I_0}{a_0}} \quad (26.)\ I_0 = a_0\, R_0^{\,2}$$

§ 42. The relations between the similar quantities for the compressed section will be expressed by the same equations with the index $_0$ changed to $_1$. So also when the upper and lower portions of the beam are symmetrical and the moduli of elasticity and rupture in tension and compression equal, by dividing the moment of inertia I of the *whole* section by the *total* area A, we have

* Compare Stoney on Strains, § 70. † Compare Du Bois Graphical Statics, page 112.

(27.) $I = AR^2 = \frac{aH^2}{2}$ and combining this with (23) and (13) we may have

(28,) $M = G\,I = G\,A\,R^2 = G\,\frac{aH^2}{2}$ which corresponds in form with (15), showing that when the gross area of equal chords and of a beam of symmetrical section are equal, $R' = R$. Evidently also unsymmetrical beam sections may be put in the form of (14), so it appears that the moment of resistance of any beam is equal to that of two chords of a girder having respectively the same areas as the sections of the beam above and below the neutral axis, when the centers of the chords are arranged at distances from the axis equal to the respective radii of gyration of the sections of the beam.

§ 43. The *radius of gyration* should not be confounded with what we have above termed the *radius of effect.* The former is the distance from the axis at which a certain area uniformly elongated in all parts of its section will support a given moment—the latter the acting distance of the *forces* arising from unequal elongation of different parts of the same area. The radii of effect are then only to be considered in connection with unequal elongations, but the integral of the forces arising therefrom being a definite quantity may arbitrarily be put equal to other quantities which are made thereby of equal value. In (27), since A is the area of the total section, R is the radius of gyration, but it is evident from the corresponding, equation (15), that A' may be any area or R' any distance, so long as $A'\,R'^2 = I$.

From (25) and (27) we may have for b constant—

(29.) $$R = \sqrt{\frac{I_0}{a}} = \sqrt{\frac{b\,h^3}{3\,b\,h}} = .577\,h$$

and from (17) and (18)—

(30.) $$r = \frac{2}{3}h.$$

§ 44. That is the centre of effort of the forces due to unequal elongation of the fibres is at a greater distance from the axis than the radius of gyration, as it evidently should be. It is not necessary to find the value of r for symmetrical sections when the modulus of elasticity is considered constant, but it has an important bearing in the more general consideration of the subject, for which preparation has now been made.

§ 45. Resuming for a time the consideration of a skeleton girder we may obtain from (8) by equating the two values of M.

(31.) $a_0\,E_0\,R_0\,P_1 = a_1\,E_1\,R_1\,P_0$ which shows that the distances R_0 and R_1 and consequently the elongation of the chords which are proportional thereto, vary directly as the lengths elongated, and inversely as the areas and moduli of the chords. The lengths P_0 and P_1 elon-

gated will generally be equal. In such cases which include those where flexure takes place at every section we may have.

(32.) $R_0 : R_1 :: a_1 E_1 : a_0 E_0$.

Hence, when the modulus is constant, the neutral axis divides the effective height H into distances R_0 and R_1 inversely proportional to the adjacent areas of chords, or practically of the flanges of a beam, and when the areas of the chords are equal the distances R_0 and R_1 are inversely proportional to the moduli.

§ 46. From (14) with value of G from (10) we have—

(33.) $\frac{f_0}{c_0} a_0 R_0 = \frac{f_1}{c_1} a_1 R_1$. Making the values of c, equal those of R, and the values of f equal T_0 T_1 the moduli of rupture of the material in tension and compression respectively, we have—

(34.) $a_0 : a_1 :: f_1 : f_0 :: T_1 : T_0$:

That is the areas of the chords of a girder should be proportioned to the ultimate strengths or moduli of rupture of the material in tension and compression, which is evidently true (though not always practicable on account of crippling), and explains the efficiency of the Hodgkinson beam in connection with principles previously adverted to, § 7. It will be noticed however that this expression takes no account of the deflection previous to rupture.

APPENDIX B.

Development of Formula for transverse strains on the basis that the relations of the strains to the elongations vary according to experiment, instead of in proportion to the elongations.

§ 47. Representing the abscissæ of the curves as plotted by x, and the ordinates by y, the value of the latter may be expressed.

(35.) $y = \varphi(x)$. Substituting x in place of v in (17) and (18), the value of the function of x may be used instead of one factor, x. The integral of (17) will then give the area of the plotted curve, between the limits assigned, and of (18) the moments of its ordinates, which may also be obtained graphically when necessary or more convenient. The values of these integrals must then be modified to represent the relations in terms of the actual values of the elongations and strains. Putting $Y =$ actual strain where the corresponding ordinate of curve $= y$, and $s =$ the maximum value of x considered, the special values due to the scale of the plotted curve may be eliminated by dividing the integral by a special value of y, which is involved once, and by the value of s, repeated as many times as x is involved after integration. When the special values are eliminated, s refers only to the depth of the section, and h is substituted

in its place. The equations referring to the extended section based on (17) and (18) are then—

(36.) $$N=\frac{Y_0\, b_0\, h_0}{ys}\int_0^s \varphi(x)dx$$

(37.) $$Nr_0=\frac{Y_0\, b_0\, h_0^2}{ys^2}\int_0^s \varphi(x)xdx$$

§ 48. Unless specifically mentioned y_0 will hereafter refer to the maximum tensile ordinate, when $x=s$ and y_1 to the compression ordinate, when $x=s$, but which will not be the maximum ordinate in case the neutral axis shifts. If the strains in the compressed section be considered proportional to the elongations, as most of the curves show is practically true within the limits required, and the tangent of the angle at the origin be put equal to g, then $y=gx$ and—

(38.) $y_1=gs$ and we may have

(39.) $$N=\frac{Y_1\, b_1\, h_1}{gs^2}\int_s^0 gxdx=\frac{b_1\, h_1\, Y_1}{2}$$

(40.) $$Nr=\frac{Y_1\, b_1\, h_1^2}{gs^3}\int_s^0 gx^2\, dx=\frac{b_1\, h_1^2\, Y_1}{3}$$

§ 49. The final results in this case are the same of course as would be obtained by using equations (17) and (19) direct. Putting the numerical co-efficients derived from the integrals in (36) and (39)$=m_0$ and m^1 respectively, and, those from (37) and (40)$=n_0$ and n_1 respectively, we have at once (41) $m_1=\frac{1}{2}$ (42) $n_1=\frac{1}{3}$. Put also $\frac{y_0}{y_1}=t$ and $\frac{b_0}{b_1}=j$

§ 50. Equating (36) and (39), we have

(43.) $m_0\, b_0\, h_0\, Y_0 = m_1\, b_1\, h_1\, Y_1$, hence

(44.) $$Y_1 = 2m_0\,\frac{b_0\, h_0}{b_1\, h_1}\, Y_0$$

We may have also

(45.) $Y_0 : Y_1 :: y_0 : y_1\frac{h_1}{h_0}$ which permits the neutral axis to shift by modifying the value of Y_1 in proportion to the decrease of h_1 in relation to h_0, hence

(46.) $$Y_1 = \frac{y_1\, h_1}{y_0\, h_0}\, Y_0 = \frac{h_1}{th_0}\, Y_0$$

§ 51. Equating (44) and (46), we find, easily,

(47.) $b_1\, h_1^2 = 2m_0\; t\; b_0\, h_0^2$

(48.) $h_1 = \sqrt{2m_0\, jt}\; h_0$, hence

(49.) $D = h_0 + h_1 = (\,1 + \sqrt{2m_0\, jt}\,)\; h_0$

From (20), (37) and (40) we have

(50.) $$M = N\,(r_0 + r_1) = n_0\, b_0\, h_0^2\; Y_0 + \frac{b_1 h_1^2\; Y_1}{3}$$

$$=\left(n_0+\frac{2m_0}{3}\sqrt{2m_0\, jt}\right) b_0\, h_0^2\; Y_0,$$

and when $b_0 = b_1$

$$(51.)\quad Y_0 = \frac{M}{\left(n_0 + \frac{2m_0}{3}\sqrt{2m_0\,t}\right) b_0\, h_0^2} = \frac{(1+\sqrt{2m_0\,t})^2 M}{\left(n_0 + \frac{2m_0}{3}\sqrt{2m_0\,t}\right) b_0\, D^2},$$

§ 52. When the neutral axis is central, the breadth uniform and the strain referred to the outer fibre, we may have from (21), and in another form from (50).

(52.) $f = Y_0 = \frac{6M}{bD^2}$ which, according to the ordinary theory, should equal the ultimate longitudinal resistance of the material per unit of section, but which, as has been explained, always gives in respect to materials mentioned, results much in excess of those obtained by direct application of longitudinal strain.

§ 53. Equation (51) was first applied to one of the curves numbered 8, which being taken from a tortion machine, it was thought would from increased elongations show a maximum shifting of the neutral axis. An equation in the form $y = ax^3 - bx^2$ was found for positive fractional values of x, to give the upper portion closely within the limits desired, and the compression and one-half the tension branch was considered a straight line in accordance with popular views on the subject. On this basis Y_0 was found equal to 4.316 $M \div bD^2$, or insufficient to account for the discrepancy (compare with § 52).

§ 54. The upper part of curve 3 was found to be represented approximately by the equation $y = 28.977 - \frac{122.62}{x + 3.547}$ which gives the curve shown by the dotted line. A portion of the tensile and a larger portion of the compression curve is represented closely by the inclined straight line shown, the equation of which is $y = 3.482$. This line being tangent to the tensile curve where $\frac{dy}{dx} = 3.482$ and $x = 2.387$. The results are given in § 19.

§ 55. Curve 7, which, as stated previously, was obtained from experiments on direct tension, was found to agree closely with the equation $y = 36.75 - \frac{202.125}{x + 5.5}$ and on the basis that the line representing the co-efficient of resistance was tangent to the curve of elongation at the origin, Y_0 was found equal to 4,061 $M \div bD^2$, in which the co-efficient is considerably too large to account for the discrepancy.

§ 56. No calculations have been made in respect to curves 5 and 6. They are presented as part of the evidence on the subject, but not agreeing with the other curves in the angle of the compressive branch compared with the tensile, are reserved for further investigation.

§ 57. For convenience in laying down the isodynamic curves referred to in § 24–25, the approximate equation of some of the curves was found in the simple, general form of

(53.) $y = \varphi(x) = \alpha x^n$ The equation

(54.) $y = 1.5305\, x^{.79}$ represents very satisfactorily the tensile branch of curve 1, showing the results of Mr. Hodgkinson's experiments with Low Moor Iron No. 2, and an equation of this form can always be applied to such portions of any curve as are most important (see § 24). The function in this form is convenient and useful, from the fact that a simple solution may be obtained before substituting in any special values.

§ 58. From an inspection of (18) and (37) and explanations in § 23 it is evident that the moment of resistance of all the fibres in one section, that extended, for instance, is expressed by the equations referred to, entirely independent of what the other section may be. Nr, which put equal m', equaling a certain moment, independent of the value of the total moment, $M = N\,(r_0 + r_1)$. Substituting the value of $\varphi(x)$ from (53) in (37), we have then

$$(55.)\quad Nr = m' = \frac{Y_0\, b_0\, h_0^{\,2}}{y\, s^2} \int_0^s \alpha x^{n+1}\, dx = \frac{Y_0\, b_0\, h_0^{\,2}}{\alpha s^{n+2}} \left(\frac{\alpha s^{n+2}}{n+2}\right) = \frac{Y_0 b_0\, h_0^{\,2}}{n+2}$$

$$(56.)\quad Y_0 = \frac{m'\,(n+2)}{b_0\, h_0^2}$$

§ 59. If Y represent the strain on any fibre at a distance x from the axis, Y_1 representing the strain on outer fibre when $x = s$ we may have from (53).

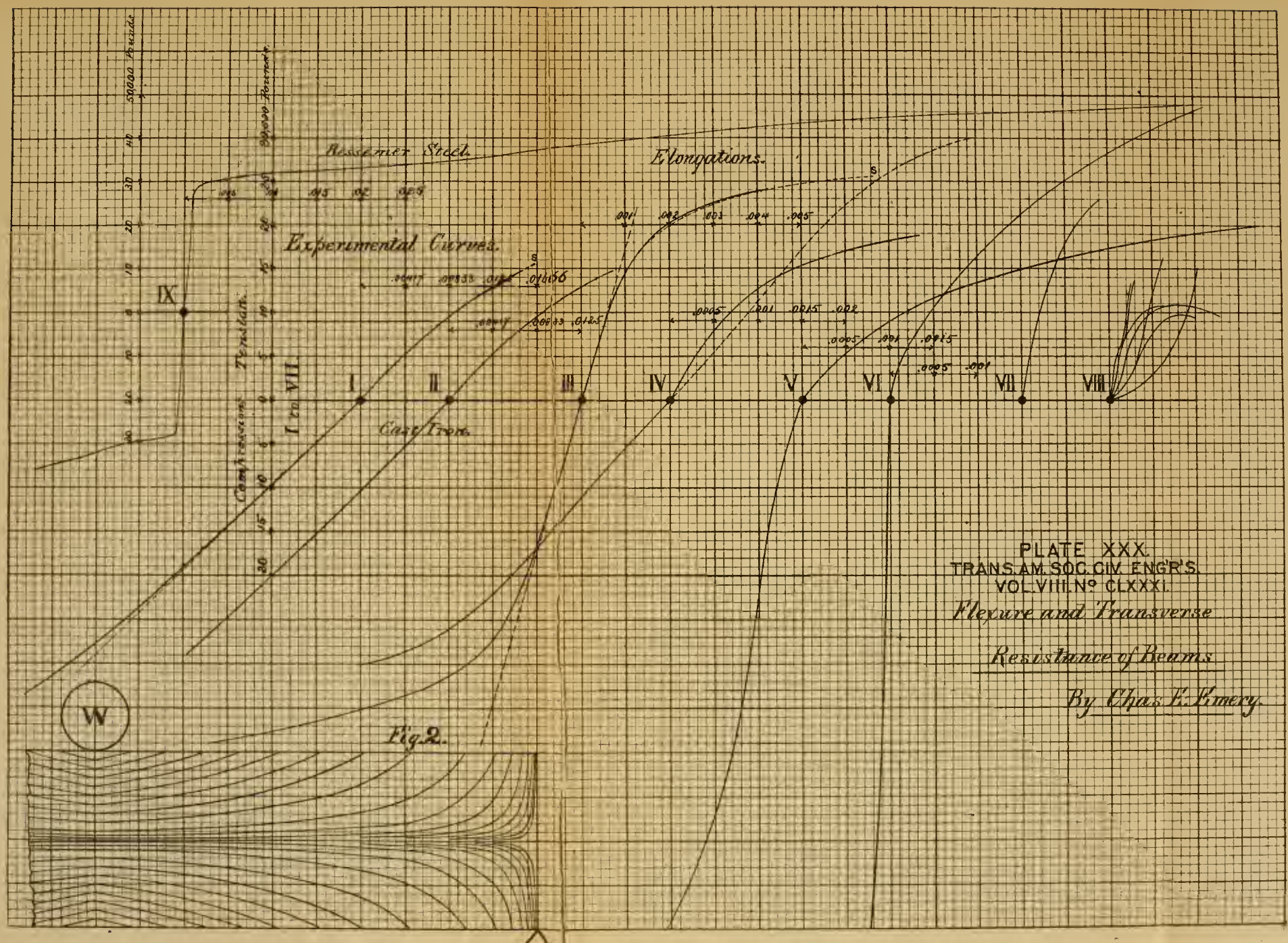
(57) $Y_0 : Y :: \alpha s^n : \alpha x^n$ from which proportion and (56) we may have

$$(58)\qquad Y = \frac{x^n}{s^n}\, Y_0 = \frac{m'\,(n+2)}{b_0\, h_0^2} \left(\frac{x}{s}\right)^n$$

§ 60. If we put $k = \dfrac{x}{s}$, or the proportion of s considered, it will, when s takes its ultimate value, h_0, § (47), represent the proportion of the depth of the tensile section considered, and we may have

$$(59)\qquad Y = \frac{k^n\, m'\,(n+2)}{b_0\, h_0^2} \qquad\qquad (60)\qquad k = \left(\frac{Y b_0\, h_0^2}{m'\,(n+2)}\right)^{\frac{1}{n}}$$

§ 61. From the above it will be seen that for any fibre parallel with the neutral axis (k constant) the strain or unit force Y is proportioned to the moment. For Y constant (60) is the equation of the isodynamic curve, and shows that k, or the proportional distance from the neutral axis in terms of the height, varies inversely as the nth root of the moment—all the terms in the equation being constant except m'. The isodynamic curves are discussed in connection with illustrations in § 25 of the paper.


Bessemer Steel.
Elongations.
Experimental Curves.
Cast Iron.
Compressions. Tensions.
Fig. 2.
I
II
III
IV
V
VI
VII
VIII
IX
W
S
PLATE XXX.
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VIII. No. CLXXXI.
Flexure and Transverse
Resistance of Beams
By Chas. E. Emery.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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CLXXXII.

(Vol. VIII.—July, 1879.)

ON THE FLOW OF WATER IN RIVERS.

By DE VOLSON WOOD, C. E., Member of the Society.

PRESENTED AT THE ELEVENTH ANNUAL CONVENTION, JUNE 17, 1879.

Read July 16th, 1879.

At the Convention of the Society in June of last year, held in Boston, the eminent hydraulician, James B. Francis, reported the result of an experiment made by him, which showed that the water at the bed of a stream of water gradually rises to the surface. He placed a white substance, having about the same specific gravity as water, at the bottom of the stream, leaving it in such a condition that the moving water would take with it some of the substance; and he observed that the water thus colored rose to the surface at a point some distance below where it was placed. This, so far as I know, was the first definite statement of this mode of action in streams of water. In the discussion which followed, I stated that admitting the correctness of the principle stated by Mr. Francis, it followed that the water at the surface must necessarily find its way to the bed of the stream, and that this action

might enable us to account for the fact, now generally admitted, that the point of maximum velocity in the cross-section of a flowing stream is not at the surface, but at a point below the surface, generally between the surface and the half depth of the stream. My view, as then expressed, was that gravity acting upon the particles during their descent would accelerate, or at least would tend to accelerate, their motion ; and that the action of gravity, combined with the motions impressed by the mutual actions of the particles, might account for the position of the point of the maximum velocity. This view I still believe to be correct, and I desire in the following paper to consider more in detail some of the principles herein involved.

The earliest experiments showed conclusively that the velocity at different points in the cross-section of a stream was not the same—that it was greater near the middle than at the sides of the stream, and greater at the surface than near the bottom. Improved apparatus and more careful experiments led to the statement that the maximum velocity was at the surface, and that it decreased with the depth, though not as a direct single function of the depth. Some assumed that the curve of velocities would be represented very nearly by a parabola whose axis was vertical and whose vertex was at some unknown distance below the bed of the stream (see D'Aubisson's Hydraulics). Most of the earlier experiments were made upon rectangular canals of comparatively small depths and of comparatively small beds—conditions not realized in the more important streams. and which, on account of the small dimensions of the cross section, rendered it impossible to determine by direct measurement the velocity at all points with sufficient accuracy to enable us to detect the true point of maximum velocity. It was in connection with experiments upon such a canal that M. Bazin, about the middle of the present century, concluded that the maximum velocity at the middle of a stream was at the surface, although he admitted that between the middle and the sides the maximum velocity would be a short distance below the surface (see Morin's Hydraulique).

Experiments upon rivers of considerable size have shown that the point of maximum velocity is below the surface of the stream.* Since the discovery of this principle, many writers attribute the loss of surface

* See Ellet on the "Mississippi and Ohio Rivers," 1853 ; Boileau, "Traité de la Mesure des Eaux Courantes," 1854 ; Darcy et Bazin, "Recherches Hydrauliques," 1865 ; "Report on the Physics and Hydraulics of the Mississippi River," by Captain Humphreys and Lieut. Abbot, 1861 ; Morin's Hydraulique.

velocity to the frictional resistance between the water and the superincumbent air. But this assumption was disproved by Humphreys and Abbot, by finding that when the wind was blowing down stream with the same velocity as the surface of the stream, or even with a greater velocity, the point of maximum velocity was still at a perceptible distance below the surface. Boileau was satisfied from his experiments that the diminution of velocity from the maximum to the surface could not be attributed to the frictional resistance of the air. He says: "We must seek for an explanation of this phenomenon principally in the mutual actions which bind the particles to each other, and in the oblique and rotary movements among the particles which result from these mutual actions and the unequal velocities of the neighboring particles." This statement, made a quarter of a century ago, contains sound philosophy, and furnishes a *general* explanation of several phenomena, the particular reasons for which it is not so easy to assign. For instance, it is not easy to explain why particular whorls are formed in water, or why they take a particular path, or why the water in a deep stream appears to boil, or why parts of a stream, in certain cases, flow up stream while the general declivity is down stream, &c.

The path of a particle in a stream of water of uniform *régime* is exceedingly tortuous. The experiments of Francis, cited at the beginning of this article, show that the particle leaves the bed of the stream and ascends more or less gradually to the surface, and as this may take place with all the particles, it necessarily follows that those at the surface must descend to the bed. We are not, however, dependent upon this experiment for establishing the fact. Any one, by observing a stream of say 5 or 6 feet or more in depth, can see that the surface appears to boil. This is caused by the ascent of bodies of water rising from some depth to the surface, and there spreading out upon the surrounding water. It thus appears that the particles, instead of moving among each other like filaments, go in bodies like streams of a few inches—or sometimes of a few feet—in diameter moving through the main body of the water. Or, possibly, these bodies are more like spheres, or other inclosed masses of water, passing from the bed of the stream to the surface, where they spread out, and afterwards form new combinations.

The motion here referred to is mostly in a vertical plane, but similar causes produce lateral movements. Every body projecting from the

shore into the stream deflects the water, causing a wave-like motion extending from the shore to, or past, the middle of the stream. The retarding influence of the sides of the stream will cause a lateral action, just as the resistance of the bed of the stream causes a vertical action; and as the water along the shore goes more or less gradually towards the centre, it follows that the water along the centre must move laterally outward to supply the place of that which leaves the shore. It is hardly necessary to note the fact that the lateral movement is not in a plane, nor that its intensity is small compared with the vertical action, although it is an element not to be entirely ignored in considering the general problem. Since both the vertical and lateral actions are induced by the forward movement of the water in the stream, we might expect that there would be a greater accumulation of water where the velocity is greatest; and such is known to be the case, the water being highest at that point in the transverse section when the velocity is greatest. The cause of this elevation is not due to the lateral and vertical actions, but rather to the fact that the lateral pressure of a fluid diminishes as its velocity increases.

It is highly probable that the vertical movements originate at the bed of the stream, for any irregularities, such as small asperities due to a sandy or gravelly bed, or sticks or weeds, or changes in the slope of the bed, will cause the water either to ascend or descend. Since the density of the water is uniform throughout, it will, when once deflected upward in its course, continue to rise until it reaches the surface unless arrested by the downward movement of other bodies of water. We have reason to believe that this action is continually going on even where its presence is not easily detected by direct observation. It must, however, be kept in mind that these vertical and lateral movements are only secondary to the longitudinal one, and hence enter, not as a principal, but as a modifying cause. Granting these premises, it follows that the apparent, or measured, velocity at any point of a stream of water is the resultant of the volocities of many particles, and is not necessarily the actual velocity of any of them—some particles moving laterally in reference to the measuring apparatus, some slower and some faster than the measured velocity.

As any body of water is rising vertically in the stream, its motion is retarded by gravity, and as it starts with a slow velocity at the bed it acts upon all the water through which it passes, tending to retard the

velocity of the stream, while the stream by acting upon this mass tends to impart to it the same velocity as the stream. There is a tendency towards a common velocity between the stream and rising mass, but observation shows, as cited above, that, in many cases, the motion of each is distinct from the other. Such is particularly the case where the surface has the appearance of boiling. I do not now see how the ascending mass can account for the maximum velocity being below the surface. But the descending mass will have its motion accelerated by the action of gravity, and if there were no resistance, this acceleration would go on till the mass reached the bottom, like the motion of a projectile in a vacuum. But as the mass descends it comes in contact with water which is moving slower than itself, and hence its velocity will be retarded. But we notice particularly that for a certain fraction of the depth the velocity may—when the vertical action is not considered—be *nearly* uniform, hence when the descending mass passes through it with a tendency to acceleration it will at first impart to the surrounding water an increased velocity, and this increase may be sufficient in many cases to cause the velocity below the surface to actually exceed the velocity at the surface. We cannot, however, at this stage of the theory, assert that this is the only, or even that it is the chief cause of surface diminution of velocity. It is possible that the lateral surface movement, caused by the action of the sides of the stream, as previously stated, is quite as important an element as the preceding.

Having indicated that the lateral and vertical movements may account for the point of maximum velocity being below the surface, we will suggest that a more critical study of the results of experiment and observation may confirm or modify this view. Thus, in a rapid, deep stream we would expect the point of maximum velocity to be deeper when the bed is rough and rocky than when it is smooth and regular. A study also of streams of different widths, but of the same depth and general character of bed, would enable us to judge more accurately of the effect of lateral movements.

These views also enable us to explain certain other phenomena. For instance, it has long been known that a boat of considerable dimensions will float down a stream more rapidly than the surface water. That this is the fact is known by observing that the boat floats faster than chips and small pieces of boards in the immediate vicinity of the boat. The latter objects being small will be resisted more in proportion to their

weight than larger ones, and hence will move with nearly the same velocity as the water in which they float. Some have attempted to explain the rapid motion of the boat from the fact that it extends downward into the more rapidly moving elements; but this explanation does not appear to be sufficient, for the velocity of the boat, in some cases at least, exceeds the maximum flow of the water. We submit the following explanation: The boat, in floating down stream, is partly in the condition of a body moving down an inclined plane, and, as such, may be considered as having a velocity independent of the stream. If we could conceive of the water in a stream having no velocity and offering no resistance (or only a very slight resistance) to the movement of the boat, the boat would (or at least might) slide down the plane. But in the actual case, the water does move, although it does not, as we have seen, go *directly* down stream. The boat slides (so to speak) down stream, but the particles of water pass from the bed to the surface, and from the latter to the former; also from the side to centre, and from the centre outward, so that while the boat is taking a direct line down stream the water on which it is gliding is wandering about, taking comparatively long journeys.

We see from this that the *laminar* theory (so to speak) in which it is assumed that layers next to the bed of the stream remain in contact with it, and that the successive laminæ retain their relative positions is no longer tenable. Also that the supposed frictional resistances between consecutive surfaces will not account for all the varying velocities. Also that these lateral and vertical movements have an important bearing upon the phenomenon of "back water." Also that much of the so-called "frictional resistances," or resistance due to the adhesion between the particles, may be explained by these movements.

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DISCUSSIONS AT THE ELEVENTH ANNUAL CONVENTION ON PAPER CLIX.

ON THE THEORETICAL RESISTANCES OF RAILROAD CURVES.*

By S. WHINERY, C. E., and J. F. FLAGG, C. E.,
Members of the Society.

S. WHINERY.—The larger part of the criticism and discussion of the paper presented by me (No. CLIX), that has come to my notice, is contained in private letters to me from friends and those interested in the subject of which it treats. The great diversity of opinions expressed shows that the subject is a complex one, and that the ideas held by many of us are neither clear nor exact.

I am confirmed in the opinion that theoretical and analytical investigation is likely to be of great value in reaching a final solution of the problem of curve resistance, and devising means to obviate it.

If it is objected that final and absolute results can never be reached in this way, we may answer that experiment has not, so far, given satisfactory and conclusive answers to the problem. Together, theory and experiment may furnish the desired solution.

In reviewing the discussion offered, I shall not confine myself to that published in the "Transactions," but will refer to such private criticism as seems worthy of attention.

The discussion by Mr. Chanute, contains, probably, the best summary in the English language, of the results of experimental researches on curve resistance, and is of great value to engineers.

* Vol. vii., page 79. April, 1878.

As was to be expected, the greater part of the criticism brought to my notice was directed toward the vexed question of coned wheels. Mr. Chanute, in referring to this part of the paper, misapprehends the conclusion arrived at by me as to the effect of coned wheels on curves of radii not falling under certain limits. The conclusion is stated at the top of page 91 of the April, 1878, Transactions, in this language: "Hence, we are forced to conclude that the coned wheels of a car will adjust themselves to any curve whose radius is not less than the altitude of the cone, of which the wheels in the position of greatest difference of diameter, forms a frustum;" and the reasons which lead to this conclusion are given on the page preceding. As yet, I am not able to see that these reasons and the conclusions to which they lead are erroneous, unless it be in the omission of the element of parallelism of axles from consideration. Whether this omission is permissible or not is a question that admits of debate. On a curve of the radius stated in the paper (1,887 feet), if the axles were placed in a radial instead of a parallel position, they would be .016 feet nearer together at the inner than at the outer wheels. If this amount be divided between the four bearings of the axles it will be about $\frac{3}{64}$ inch at each; now, there are very few trucks that will not allow of this amount of play in the bearings of the axles or the boxes.

But admitting that the axles are held rigidly parallel, the power required to make the wheels follow the curve is not great. If a four-wheeled truck, having its axles fixed in a parallel position, and having the wheels on one side smaller than those on the other side, be placed on a plane surface and rolled forward, it will not move freely. Either the smaller wheels will be slipped on the plane an amount equal to the difference of circumference of the larger and smaller wheels, and the truck will move forward in a straight line, or the larger wheels will be slipped latterly, in which case the motion will be deflected toward the side with the smaller wheels, and the path of the trucks will be a curve. The force required to slip the smaller wheel longitudinally, and the larger wheels laterally, is probably about the same; but the former acts upon the truck through a lever arm equal to the gauge of the track, and the latter with a lever arm equal to the wheel base of the truck, and where the wheel base is longer than the gauge, as is always the case in practice, the truck will move forward in a straight line; but if the truck

were so constructed that the wheel base was shorter than the gauge, the conditions would be reversed, and the truck would move in a curve whose radius would have a constant ratio to the difference in circumference of the larger and smaller wheels.

This fact, which the writer has verified by experiment, seems to have been overlooked by other investigators who have constantly maintained that "a car truck will always move in a straight line whether the wheels on one side be of the same or a different diameter from those on the other."

Assuming that my position is correct, it is clear that if the wheel base and the gauge are just equal the lever arm of each resistance would be equal, and a slight impulse would determine the direction of the motion within certain limits. In the ordinary car truck with a wheel base of 6 feet, the tendency to move in a straight line is to the tendency to move in a curve as 6 feet is to 4 feet 10¼ inches. Hence the conclusion that the force required to guide such a truck around the curve specified is not of much magnitude, and that the effect of parallelism of axles has been generally overestimated.

As to the resistance caused by coned wheels on straight track, the conclusions of the paper are probably erroneous. I had hoped that Mr. Chanute would be able before this meeting, to extend his experiments on the area of the surface of contact between wheel and rail, to ordinary car wheels. It will be remembered that his former experiments were with engine driving wheels whose steel tires are not allowed to become so much worn as the ordinary car wheels contemplated in the paper. His experiments show that the line of contact between wheel and rail, across the latter, is for engine drivers "partly worn," ¾ inch each, and in the one experiment with a wheel "much worn," this line was two inches in length. The average condition of ordinary car wheels is probably not far from a mean between the conditions "partly worn," and "much worn," and these experiments would seem to confirm the value assumed for this line in the paper.*

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* Mr. Chanute handed me, a few minutes before the above was read, a table giving the results of a large number of experiments, made very recently, to determine the area of the surface of contact between ordinary car wheels and the rail. Several of these were made with wheels worn so concave that they made two surfaces of contact instead of one.

Rejecting these latter, the average of twenty experiments gave a surface of contact 0.31 inch by 0.36 inch, the latter being the average length of the line of contact across the rail. These clearly prove that the length assumed for this line in the paper is erroneous.

The most valuable criticism of this part of the paper that has come to my notice, is contained in a private letter from my friend W. A. Gunn, member of the Society. Referring to the theory set out in the paper, as to the resistance caused by this line of contact, he says:

"This theory might be correct if the top of the rail was a plane; but the top of the rail is a convex surface, generally; and the radius of the surface of the rail most used, is not far from the radius of the ordinary car wheel. The contact of these two cylindrical surfaces would be a point, if both bodies were perfectly rigid; but not being so, the weight forcing them together, will make a line of contact both longitudinally and transversely of the rail; and it is probable that the line is longer in the direction of the length of the rail, than across it; because the rail gives under each wheel while the wheel is more rigid. The surface of contact would be something like that shown in Fig. 1, *A B* being across the rail, and *C D* in the direction of length. Now, of course, any movement of these surfaces, as a rule, will take place around the point of greatest friction, *E*, as a center. I think it will make no difference in results to estimate the effect of the friction upon one line of contact as *A B*, or on both lines, *A B*, *C D*. But considering the movement of the surfaces in contact on the line *A B*, about the *center*, instead of about the *end A* (as in your paper), would reduce the friction one-half, as shown by constructing triangles to represent it, as in Fig. 2. The sum of the areas of the triangles *A E C* and *D E B* is only one-half the area of *A B F*. Therefore, the friction would only be one-half as much as you have concluded, assuming that the top of the rail were a plane. But a comparison of figures 1 and 2 will show that the portion of the surface of contact nearest the extremities of the line, where the friction is least, move over the widest part of the triangle which represents the movement of the surfaces of contact. This would again reduce the friction at least one-half, and it would therefore not exceed one-fourth the amount you have figured out for it."

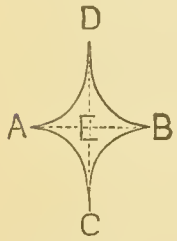


FIG. 1.

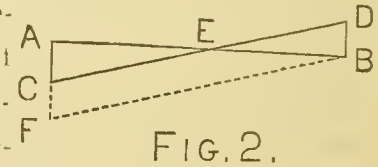


FIG. 2.

This view seems to be, with perhaps some slight modification, correct.

The position taken in the paper, that in passing around a curve, the rear inner wheel of a truck presses against the inner rail with the same force that the outer leading wheel presses against the outer rail, has been vigorously combatted by a number who have discussed the matter; several of them claiming to have demonstrated by experiment that the rear pair of wheels pass around the curve in a symmetrical position; that is, that the flanges of the wheels keep a position equidistant from their respective rails. Theoretically the position taken in the paper would undoubtedly be correct, if the wheels fit the rails accurately; that is, if there was no play between the flanges and the rails; but this is not the case in practice. With one inch play between the flanges and the rail, the longitudinal axis of the truck, must, when the outer leading flange is pressing the rail, make such an angle with the tangent to the curve, at the middle of the truck as to carry the inner rear flange away from its rail, in spite of its inclination to press it. This diagonal position of the truck on the track gives rise to another element of resistance nearly equal to that which it obviates, and the result stated in the paper is not much altered.

I have no doubt but this possibility of a truck's assuming a diagonal position on the track, taken in connection with excessive play between wheels and rails, will account for the violent oscillations and concussions observed on straight track, as well as curves, on some roads. Under such conditions, a truck may be thrown into a position on the track, where the angle between the track and the truck, as explained above, may be so great that the coning of the wheels may not be able to correct it before the forward flange is thrown violently against the rail. Whether the coned wheels are primarily responsible for these oscillations, I am not prepared to say.

I am not of opinion that it is either necessary to accuracy, or desirable for convenience, to combine formulæ Nos. 5 and 7 of the paper into one equation, as suggested by Mr. Emery. I have not taken the time to work out fully Mr. Emery's diagram (Fig. 1 of his discussion), but I do not believe that computations made in accordance with it would differ materially in result from those given by the sum of the results of the two formulæ above named.

Mr. Emery's point in reference to the force required to turn the car-body through the angle from one tangent to the other, appears, at first sight, well taken; but a little consideration will show that it is of no im-

portance. If we suppose the car-body resting at its centre of gravity on a point upon which it turns without friction, and neglect the resistance of the atmosphere, any force, however small, applied to either end, perpendicular to its axis, and in the plane of the horizon, will cause it to move, and if the force is then removed, the car will continue to revolve until opposed by a force equal in amount to the one that put it in motion. In actual practice, however, it would be necessary to overcome the friction of the support on which the body turns, and the resistance of the atmosphere. In the case of a car, with two bogie trucks, entering a curve, the leading truck would be revolved on the support through an angle equal to 90° minus the acute angle between the radius to the curve and the chord passing through the two supports of the car, and the rear truck would be revolved an equal amount in the opposite direction; but as soon as the car was fully upon the curve there would be no more motion, and, consequently, no more friction on the supports so long as the curve remained of constant radius, and, except for the very small resistance of the air, the car-body would continue to revolve without the consumption of force, until stopped by an equal opposite force, when the car should leave the curve; and, so far as track resistance is concerned, the one would counterbalance the other. There only remains the slight resistance offered by the air, which is too small to be worthy of attention.

In reference to the question of loss of power at each coupling of the train, I would refer those desiring to investigate the matter more fully, to "Coxe's Weisbach's Mechanics," Vol. I, § 152, page 283, where a full demonstration of the principle will be found.

It will be noted that the coefficient of friction is an important factor in the formulæ given in the paper, and any change in its value would modify the results accordingly. Whether the value assumed in the paper for this coefficient, is even approximately correct, is an open question. The recent experiments in England seem to prove, that the coefficient of friction decreases very rapidly as the velocity of the rubbing surfaces increases. If this is true, it would necessitate corresponding modifications of the formulæ given. Besides, it is not at all certain that the coefficient of friction is the same at a given velocity, under the various conditions of friction. Thus, the coefficient of friction for the longitudinal slip of a wheel, may be quite different from that of the same wheel, for lateral slip, while rolling forward.

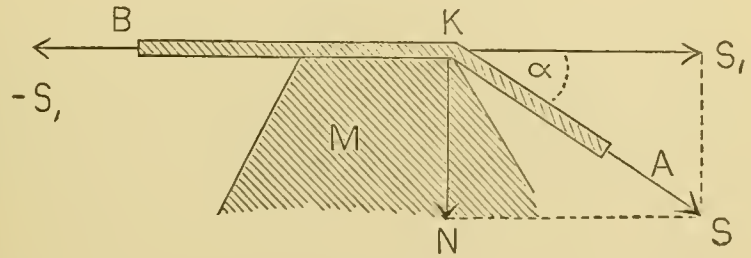
J. F. Flagg.—I desire to say a few words only in regard to section 8 of the interesting paper of Mr. Whinery, in which he deduces a loss of tractive power from the line of tractive force forming a funicular polygon.

This loss of power is disputed by Mr. Emery (Vol. VII, p. 104), but is reasserted by the author of the paper in the "Railway Gazette" for April 18th, 1879, where he endeavors to maintain his position by a reference to "Weisbach's Mechanics."

It seems to me that the author is a little at fault in his dynamics. *What work* does this lost power do? He says that "at each angle the tractive force is decomposed into two components, one of which is expended in drawing the following car along the track;" but in what work is the other component expended?

He adds, "it *tends* to move the angle itself towards the centre," but does it *do* any work of this kind? I think not. This radial force, undoubtedly, produces friction, which consumes a portion of the tractive power; but throwing friction aside, I fail to see any proper decomposition of forces that can show any loss of power from this cause.

The author refers to page 283 of Coxe's Weisbach. There the initial force upon the cord, on the polygon, is decomposed into two, one of which is perpendicular to the other, or following tension in the cord. Why should an assumption like this be made? If, instead, the former component is taken to bisect the angle formed by the cord—or in case of the railroad train, is taken normal to the curve—there will be no loss found in the decomposition; and this is the only natural way to



obtain the relation of the several forces. If section 152 (page 283) of Coxe's Weisbach is correct, by reversing the point of application of the power, from *A* to *B*, the strain upon the rope would be *increased* at the opposite extremity, an absurd result, unless other conditions are introduced. If the support, *M*, rests upon a frictionless surface parallel to

the resulting tension ($-S$,) on the cord, with the condition added that there should be a complete static equilibrium including the support, then, of necessity, this second component (N) must be perpendicular to this surface, and consequently to the resulting strain. Certainly no such conditions hold for the railroad train.

I cannot appreciate the value of this section in Wiesbach's Mechanics, the mode of decomposition of forces seems so arbitrary and unnecessary; it is entirely wanting in the earlier American edition, edited by Walter R. Johnson. And if Mr. Whinery will refer to the following chapter of Coxe's Weisbach, pp. 356 to 358, in which a rope is stretched, in the form of a funicular polygon, over several sharp angles, he will see that here Weisbach has deduced the final strain upon the cord, from the initial one, simply by obtaining the friction at each angle, and subtracting the total friction from the initial force, utterly ignoring the matter quoted from p. 283; and the example of a chain stretched on the circumference of a fixed wheel (page 359), approximating pretty nearly the case of a railroad train, is also worked out with a loss from friction alone.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

(Vol. VIII.—July, 1879.)

DISCUSSION AT THE ELEVENTH ANNUAL CONVENTION ON PAPER CLXXII.

THE USE OF COMPRESSED AIR IN TUBULAR FOUNDATIONS, AND ITS APPLICATION AT SOUTH STREET BRIDGE, PHILADELPHIA.*

By F. COLLINGWOOD, C. E., Member of the Society.

There are several things in Mr. Stauffer's paper which I wish to comment upon briefly.

The first is as to the particular arrangement of the joints in the cylinders. If I understand the drawing aright, interior flanges were separated one-eighth of an inch, when the exterior portions of the cylinders proper

* Vol. VII, page 297, October, 1878.

were in contact. Now, if the packing was always made thick enough to insure that the exterior portions did not touch each other, no harm could ensue. But if they were brought in close contact, a bending or tearing strain will be set up in the angles of the flanges, which will be so much in addition to the strain caused by the upward pressure of the air, and may become dangerous.

A case in point occurred in the sinking of some cylinders for a bridge near Fall River, several years since. I have no details at hand, but I believe the flanges of the air lock were 2″ thick; the joint leaked air, and men were sent down to tighten up the bolts. Soon after, the air lock was blown off and several men lost their lives.

The locks for the Brooklyn caisson of the East River bridge had perfectly plain flanges, and were packed with rubber rings. When the locks were used temporarily on the New York caisson for filling up the water shafts, pig iron and lead were piled upon them, as they were not considered safe for the extreme pressure then required.

In reference to the doors of air locks, two precautions are desirable: First, that the holes in the hinges be elongated vertically, so that as the pressure comes on it can compress the rubber at the hinge, as well as elsewhere; second, that a thoroughly efficient and easily-worked arrangement be provided for hoisting up the doors to the locks. This must be such that a considerable pressure can be exerted aside from merely lifting the door to place, and so secure a perfect contact, as the rubber gets hardened by use, and will allow the air to rush past it as fast as it enters or escapes from the lock. A person who has once been imprisoned in an air lock will not willingly be subjected a second time to the same ordeal.

The paper mentions 3″ diameter as the size of the equalizing pipes. It does not state whether these were opened full or not when men were passing through the lock. The physiological effects of such a rapid change of pressure as this would cause, could hardly fail to be serious. Two cocks, one inch diameter each, were used in the caissons of the East River bridge, and these openings were somewhat too great when the pressure was extreme. The heat and pressure on entering, or the cold and damp when leaving, are not pleasant experiences; but it is better to endure them a reasonable time, and avoid the possible injury to health otherwise caused.

It is somewhat remarkable that the air pressure was not used also for removing sand and mud, as well as for water.

The use of a straight pipe without water jet has been found very effective in removing sand, and is certainly more economical when the material is suitable, than the removal by bags.

From our experience in the caissons here, I have become convinced that all material can be removed more cheaply by compressed air than by any other method, where the caissons are of any size. No better method can be devised for *sand* than a perfectly straight pipe, without water jet or any other accessories. We have removed sand by a 3½ inch pipe, as fast as all the men that could work around it conveniently could shovel it to the pipe, say 20 yards per hour.

Where there are boulders, clay, or stiff mud, the air can be made to lift a cage, acting as a piston in a continuous cylinder which is connected with the atmosphere above (the cage containing the load to be removed). This system is now in successful operation in the Epinac coal basin, in France. Coal is lifted there from a depth of 2 000 feet, at a cost considerably less than by the usual method by cables. The miners all ascend and descend by the same apparatus.

The details for the application of this system to a caisson would be different, but I can see no difficulty in working out a scheme which shall be safer than a water shaft can possibly be made, which shall give a positive lift, free from the often ineffective working of a dredge; and which shall use no more air than ought in any case to escape, to keep the air in the caisson of sufficient purity.

The Epinac system is described in "London Engineering," of May 2, 1879.

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CLXXXIII.

(Vol. VIII.—August, 1879.)

THE SOUTH PASS JETTIES.

NOTES ON THE CONSOLIDATION AND DURABILITY OF THE WORKS, WITH A DESCRIPTION OF THE CONCRETE BLOCKS AND OTHER CONSTRUCTIONS OF THE LAST YEAR.

By MAX E. SCHMIDT, C. E., Member of the Society.

Presented at the Eleventh Annual Convention, June 17th, 1879.

In presenting this paper to the Society it is not my intention to discuss the question whether or not jetties have been the proper means by which to improve navigation at the mouth of the Mississippi.

A few explanatory remarks to accompany the chart of the last channel survey (Plate XXXIX), and one or two tabular statements giving in a condensed form the results that are of interest, will enable a dispassionate judgment to be formed as to the efficiency of the improvement.

A year ago a paper was read before the Tenth Annual Convention of this Society, by Mr. E. L. Corthell, the Resident Engineer, wherein he says:

"It will be remembered that the jetties are still incomplete; that "the results aimed at are not yet fully realized, and that many of the "phenomena are the results of progressive works, and are incidents "simply of the progress of channel making, at which the river has been "set at work."

To-day, in reviewing the rapid progress which has been made in the construction of the jetties and in the improvement of the channel during the last year, we can promise the speedy completion of the work.

My object is to present some plans finally determined upon to insure permanency to the works, to explain the causes that led to their adoption, and to speak of the degree of durability attained in the construction of the jetties.

In doing so, I shall endeavor to make my remarks as comprehensive as possible by referring largely to illustrations.

Introductory Notes of Interest.

1. The East Jetty begins at the old eastern land's end, and is eleven thousand eight hundred (11 800) feet long.

2. The West Jetty begins four thousand (4 000) feet below the eastern land's end nearly opposite the western land's end, and is seven thousand eight hundred (7 800) feet long.

3. The Kipp Dam, six hundred (600) feet long, connects the head of the West Jetty with the west shore, and will be treated as a part of that jetty.

4. The jetties are one thousand (1 000) feet apart, and run parallel with each other.

5. The wing dams project out one hundred and fifty (150) feet from each jetty, and are of a temporary nature generally.

6. Both jetties terminate just beyond the crest of the old bar, two and one-quarter miles seaward from the old eastern land's end.

7. The jetties are built of willow mattresses and stone.

8. Both jetties, excepting the lowest one thousand (1 000) feet, may be considered permanently raised to the level of average flood tide.

9. The top of the mattress work where brought to the surface is twenty feet wide and covered with a layer of stone about one foot in thickness.

10. Tides are diurnal, and rise one and one-half feet.

11. The prevailing winds blow from an easterly direction.

12. The mean velocity of the river current during flood stages of the Mississippi is three miles per hour.

13. During the low water stage the current decreases to three-fourths of a mile per hour, and reverse currents have been observed.

14. Gales and hurricanes are liable to happen during the equinoctial months ; highest velocity of wind observed, seventy-two miles per hour.

I.

Abstract of plans and specifications for consolidating the jetties at the South Pass, adopted and work commenced November, 1879.

The East Jetty to a point eight thousand feet and the West Jetty to a point nine thousand feet seaward, measured from the eastern land's end,

to be finished by a rounded paving of rip-rap stone on the top of the mattress work.

The centre of the pavement to follow the centre line of the jetty, the crest to be at the level of one and one-half feet above average flood tide, and the base to be twenty feet wide.

The stones to be set on edge as far as the lowest stage of the tide permits. The submerged part of the slope on the river and sea side to be built of rubble stone with an inclination of two to one.

In order to prevent leakage, gravel to be worked into the mattresses, and the top to be generally leveled up before proceeding with the paving.

Macadamized stone to be used to fill out the interstices between the larger stones composing the capping, and the slopes to be tightened in a similar manner by a liberal application of gravel and broken stone. No willow work to be visible, and the jetties to appear as though they were built of stone. On Plate XXXI may be found a section finished in the contemplated manner.

The remaining distance of both jetties, namely, three thousand eight hundred feet of the East Jetty and two thousand eight hundred feet of the West Jetty, to be consolidated by large blocks of cement concrete placed on top of the jetty. The blocks to be from sixteen to twenty feet long, from five to thirteen feet wide, and from two and one-half to four feet thick, the dimensions enlarging by off-sets as the jetties approach the sea ends.

The bottom of these blocks when put into position to rest at the plane of average flood tide, the jetties to be leveled up to that plane by large and small stone and gravel.

The blocks to serve as a foundation for a superstructive parapet, to be composed of concrete, and continuously built, from three to six feet wide and from two and one-half to four feet high.

This parapet to be applied to the lower sixteen hundred feet of both jetties.

A sufficient period of time to be allowed for the foundation blocks to settle before grading and leveling up, preparatory to the construction of the parapet.

From the upper end of the concrete work to a point six hundred feet above the extreme sea end, the river and sea slopes of both jetties to be composed of rubble stone, intermixed with macadam stone and gravel. The slope to be built with an inclination of two to one.

A rounded cap of paved stones to be carried from half the hight of the concrete foundation blocks to the lowest attainable water's edge.

For the lower six hundred feet of both jetties the sea slope to have a foundation, composed of a willow mattress, one hundred feet wide and two feet thick. On this foundation a sloping crib work to be placed, composed of palmetto piles, to be sunk by filling the compartments with large stones averaging about one ton in weight.

On the river side a similar crib work to be sunk on the rip-rap foundation already in place.

The vertical edges of the cribs to face the jetty and stand at a distance of from ten to fifteen feet from the embankment—the intermediate space to be filled with stone. Large rock to be used for covering the crib and making the connection with the concrete blocks on the jetties.

On Plate XXXII (Figs. 1, 2, 3), may be found an exhibition of the contemplated work.

The Pier Heads, at the extreme end of both jetties, to be built at right angles to the axis, and in form of a T-head to extend out on each side of that line. The foundation on the East Jetty to be one hundred and eighty feet wide and on the West Jetty seventy-two feet wide. As the surface is neared, the structure to contract so as to make the forward and side slope descend pyramidically into the Gulf, the foot of the slope on the East Jetty to rest one hundred feet seaward from the last concrete block. On the West Jetty the slope to project thirty-five feet.

In constructing this part of the work the area in advance to be leveled up by mattress work to a depth of sixteen feet below average flood tide, and thence raised to the surface by palmetto crib work held in place and covered with large stones.

The plans are subject to such modification as development of results may suggest.

II.

On the degree of durability attained in the construction of the Jetties, with an explanation of the causes that led to the adoption of the plans toward consolidation.

It will readily be understood that if these works have been as successful as it is claimed in deepening the bar at the mouth of the Mississippi from nine and two-tenths feet to twenty-seven and two-tenths

(27.2) feet, the question of their permanency must necessarily arise and involve the present and future value of the jetties.

The term "permanent" applies to all things that preserve and maintain the properties with which they have come into existence.

Strength being superlatively the original aim in the construction of sea works, *continuous* strength must be the essential for their permanency.

Hence it is obvious that the value of sea works will be proportional to the degree of strength which they possess, and, again, that any shortcoming on the part of the works, to fulfill the duties imposed, will be traced back directly to imperfections and defects in the mode of construction.

This mode of construction in the case of the South Pass Jetties has been a study in itself, as will be seen presently.

There were three destructive elements to be overcome by these works :

1. The abraiding power of the river current.
2. The momentum and impact of the waves.
3. The undermining power of the waves.

With a full appreciation of the magnitude of these forces, no design was made nor was any detail allowed to be put into the works which did not strictly adhere to the following practical laws :

1. That a broad and elastic foundation will prevent undermining.
2. That proper slopes will resist the impact of the waves.
3. That tight work will stop leakage, and
4. That work maintained at a uniform hight will obstruct the escape of water by overflow.

In these four points, or rather in their homogeneousness, lies the secret of permanent work.

The peculiar conditions under which this work has been carried on, and the many embarrassments and disadvantages which surrounded it from the start, are facts which have been well known.

At this place, and bearing upon the subject treated in this paper, I will only say that as a matter of necessity the execution of the works had to be governed in more than the ordinary sense of the word by rapidity and economy, leaving it for a future day to add such appliances as experience would suggest to maintain the strength of the works. The day to do this has arrived, as will be seen from the plans accompanying this

paper. They are the results of a long experience, a careful study and searching investigation of the phenomena which prevail in this locality.

In this connection it should be remembered that four years ago to-day, on the 17th of June, 1875, the first pile was driven in the work, and, a month later, the first willow mattress sunk close to the eastern land's end at the mouth of South Pass.

To-day the willow work may be regarded as completed, and the progress made towards consolidating the jetties by the application of heavier material has advanced far enough to foretell the period when this work will be completed, to stand an enduring monument of the capabilities of our profession.

During the construction of the mattress work the ratio of stone to willow was 1 : 5.32. This ratio may appear to be small, but it was found to be sufficient, as will be explained further on.

The specifications of the willow contract demanded flexible branches not exceeding two inches in diameter at the butts. The willows were brought a distance of about twenty-five miles. They grow in abundance along the banks of the Mississippi, above the head of the Passes, and overspread the small sub-deltas which have formed by deposits of the river at crevasses and lateral outlets where the waters have left the main stream and made a shorter road to the Gulf.

The willows were, therefore, easily obtained, cheaply transported, and were a material which, on account of its light weight, caused little wear and tear to the barges on which it was loaded.

Not so with the stone. The singular geognostic condition of the delta, followed by the total absence of rock for many hundred miles inland, made it a problem from the beginning how to procure the rock in quantities large and fast enough to allow the prosecution of the works with economy and rapidity.

During the early stages of the work, some rock—amongst which there was much granite—was obtained in New Orleans from the ballast of foreign ships. There were secured from this source nearly twenty-one thousand tons, brought from all parts of the world.

But under the pressure of incessant demand this supply soon became exhausted, and for a while rock was obtained from quarries near Vicksburg, Miss., five hundred and fifty miles distant from the jetties. This rock, however, did not answer. It contained a high percentage of loamy sand, and was brittle and permeable. The plan of drawing the supplies from that source was, therefore, soon abandoned.

The present contractors, Messrs. J. Sharp McDonald & Co., of Pittsburgh, Pa., bring the stone from quarries in the limestone region near Roseclair, on the Ohio river, thirteen hundred miles above the mouth of the Mississippi. The rock here is composed chiefly of calcareous, intermixed with quartzose elements, and has been found to possess fully the requirements of hardness, strength and weight, to make it serve the purpose for which it is intended. Weight, per cubic foot, 155½ lbs.

Rock, in any shape or size as it may be desirable for a special operation at the jetties, is furnished by the contractors in two monthly tows of about twenty barges, each barge containing an average of four hundred cubic yards of rock.

The preservation and care of the property destined for the construction of the works has been an item of great importance from the beginning, directly concerning the progress and often the safety of the works.

During the earlier stages, while the whole line of the works was much more exposed to the "abrading power of the current" and the "momentum and impact of the waves," it was a matter of unquestionable importance to always have the two materials, willows and stone, in readiness for immediate use in case damaged portions of the works needed repairing. A delay would cause tenfold the outlay of money.

The great aid which nature extended to these works in adding strength to them from its own sources (see deposit on sea side, Fig. 1 and 2, Plate XXXIII), was essentially hastened by uniformity in construction, which caused a uniform degree of tightness throughout and equable resistance to destruction.

While nobody will deny that a more liberal application of stone from the beginning might have hastened the formation of the channel, since it would have made tighter work quicker, we can unfailingly pronounce the saving in that quarter to have resulted in furnishing valuable data on the strength and dimension of cross-section required to resist the current of the Mississippi and the waves of the Gulf.

Under more auspicious circumstances, if, for instance, the whole amount of money appropriated for this enterprise had been available at the commencement of the work in June, 1875, precautional measures might have been resorted to, consisting chiefly of greater area of pier-section, which, although perfectly legitimate, would have been superfluous, as is shown by the course of events during the four years of jetty construction.

This point is illustrated by Figs. 1 and 2 on Plate No. XXXIII, Fig. 1 shows the manner in which it was intended to finish the pier section at a point four thousand two hundred feet seaward from the Eastern Lands-end, while Fig. 2, which gives the actual condition in which the jetty is built, enables us to compare the two. It should be stated that the foundation mattress on the sea side for a distance of three thousand feet was sunk under misconstruction of orders. No human engineering could have constructed a more sheltering protection than that which is obtained by the deep deposit of sand which has accumulated on the sea side over an area of many hundred feet in width, skirting both jetties in their march over the crest of the bar.

In explaining the causes that lead to so vast a deposit of sedimentary matter, the order in which the construction of the jetties was carried on furnishes the best criterion.

It will be remembered that the entire length of the foundation of the jetties, from the lands-ends to sea-ends was laid, before the second tier was applied; and again, that the entire second tier was placed and sunk on the foundation, before the third tier was commenced, and so forth, until the surface was reached.

The jetties have therefore been raised with a uniform degree of vertical progress over their entire length.

In doing this, it was observed that each tier of mattresses caused a shoaling on the sea side corresponding in hight with the thickness of the mattresses in place.

This was due to the obstruction which was placed in the way of each successive layer of current, stopping the flow sufficiently to cause the sediment to precipitate on the other side.

As the jetties grew up, and commenced to confine the volume of the pass, the water was largely charged with additional sediment due to channel erosion. But, by limiting the potency of the current to the channel between the jetties, no suspending power existed to carry the load of sediment over that portion of the bar which was not jettied.

It was dropped therefore on the crest and on the landward slope of that bar, building up a chain of successive reefs, as the bottom neared the surface. New Pelican reef, Base-line reef, and Reef Extension (see Chart of Channel, Plate XXXIX), are such new formations.

The numerous advantages of the sea side deposit were fully appre-

ciated, and measures taken to induce by means, based upon the same laws, a similar deposit on the river side.

For this purpose, a system of wing or spur dams was built, each wing dam jutting out one hundred and fifty feet from, and at right angles to the main line of the jetty. Although rapidly constructed, and with no view to permanency, these wing dams have been most effective in giving protection to the jetties and hastening channel erosion. The current is stopped above and below the dams; the sediment drops and a bank forms.

On Plate XXXIV are two comparative sections of the channel between the jetties, Fig. 1 showing the condition before, and Fig. 2 the condition after the wing dams were built. The effects are plainly visible.

The channel between the jetties, although intended to be one thousand feet, is at present only about seven hundred feet in width; but while the channel depths are allowed to increase in proportion to the greater contraction of the channel way, the jetty embankments are removed behind a sheltering bank of deposit which is braced and stiffened, as it were, by the tilted mattresses composing the wing dams.

Of the entire length of the jetties all but the last two thousand feet at the extreme sea ends, have received these protective deposits on the river and sea side.

It is evident from the plates and drawings presented that ninety per cent. of the willow work composing the jetties is immovably bedded in the deposits of the river.

No such thing could have come to pass if the water of the Mississippi did not contain the vast percentage of sedimentary matter which it carries to sea annually. But in such a case there would have been no delta, no bar and no jetties. Thus, the sediment itself becomes one of the agencies in removing the deposits of centuries.

An opinion may now be formed of the durability of both jetties from their starting points to within two thousand feet of the sea ends.

Safety of foundation, proper slopes, tightness and protection from overflow being the points to be examined, it is believed that the following points have been conclusively proven:

1. That the foundation is absolutely safe.

2. That the slopes of the work are protected by natural slopes, formed of the mud, sand and clay deposited by the river.

3. That tightness has been obtained for the jetty embankments to a degree very nearly equal to that of the natural banks of the pass, the only difference being that the top mattress is not yet filled with the mud, and, therefore, the leakage not completely stopped.

4. That the protection from waste of water by overflow is checked to the datum plane of average flood tide.

Hence, referring back to the plans adopted for consolidating the first eight and nine thousand feet of the jetties, it will at once be seen that the only remaining point, on the strength of which the permanency of this part of the jetties might be questioned, has been carefully considered.

The compressive strength of the proposed paving, in combination with the gravel and small stone, that is to be filtered into the mattresses, will have the tendency of stopping any superficial or lateral escape of water, with the ultimate result of turning it into its legitimate course between the jetties.

Nothing has been said, so far, of the sea ends of the jetties, except the description of the plans designed for their permanency.

The term "sea-ends" applies to the lower parts generally, without clearly defining their limits. It is understood, however, that as soon as the jetties emerge from the shelter of the reefs, the degree of exposure increases, and continues to increase, until the extreme ends are reached.

By far the most troublesome parts to maintain have always been the lowest six hundred feet of both jetties.

In planning the construction of the lower ends, the expediency and importance of a larger pier-section were amongst the special features of the original designs. But, as has been already remarked, the vital point, upon which success depended most, was a rapid and economical construction. The money to carry on the works had to come from sources opened by the success which the works themselves would produce, and, under the weight of the circumstances, the area of pier section was increased but slowly in the beginning.

The repairs which from time to time became necessary, made it imperative, however, that, at the earliest possible moment, such measures should be taken as would bring up the lower ends of the jetties to the standard of strength required for their permanency. The plans adopted aim at the accomplishment of this purpose.

In the development of this subject it should be stated that in addition to the three destructive forces already mentioned, two new elements were here introduced, which became detrimental to the jetties and delayed rapid construction. We refer to the subsidence of the bottom and to the depredations of the worms.

The subsidence of the bottom and the natural compression of the willow work, are items that should be distinctly kept apart. But the analogy in the effects of both made it difficult to ascertain their extent correctly and separately.

However, the depression of the surface of the work has been carefully observed from bench marks, established on some of the best settled old piles. The co-efficients of shrinkage thus obtained with reference to the original depth were :

At the upper end $= 0.33 \times$ depth.
At the sea end $= 3.00 \times$ depth.

Both values include compression of willows and subsidence of the bottom, with the strong probability that the mattresses were equally compressed throughout, by yielding their elasticity, while the actual subsidence varied with the consistency of the bottom.

Accepting one-half of the total depression, as found at the upper end, as being due to compression, and the other half as being due to subsidence, we have the elements of an equation by which to ascertain the amount of actual subsidence which took place at the sea-ends of the jetties, namely :

$$S = 4d\left(1 - \frac{0.33}{2}\right) - d^*$$

It was not until the fall of 1877 that, after adding tier upon tier of mattress and increasing thereby the weight of the whole structure, the foundation was forced through the quick-sands below, and struck a bed on the older, harder and firmer strata of bar deposit.

Near the extreme end not less than sixteen tiers of mattresses have been sunk, representing a vertical hight of twenty-six and three-fourth feet of compressed willow work. The original depth of this place was eight feet, from which we conclude that eighteen and three-fourth feet of the work are below the original bottom of the bar.

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* d stands for original depth of bottom.

It may be added that the rate at which this sinking proceeded was very marked in the beginning, but since the fall of 1877 the the tendency has greatly decreased, if it has not stopped entirely.

Engineers will understand the difficulties which surround the observer who tries to follow up a system of levels on a territory likely to sink with his bench marks a fraction of a foot daily. We can do no otherwise than regard the results coming from such sources as approximations.

As to the depredations by the worms it should be stated, that out of twelve months of the year, seldom more than three months have been favorable for the worm to work. During these three months, which embrace the low water stage of the Mississippi, September, October and November, the surface water is brackish at the mouth and in the Pass, and it is salty or nearly so from a depth of five feet down, near the end of the jetties and seawards (hydrometrical reading 1 010 at 60° temperature.)

During the construction of the jetties, the following facts have been elicited, bearing on this question :

1. No traces of worms have ever been found above a point ten thousand feet below the Eastern Lands-end.

2. Below that point ravages of the worm have been observed, chiefly resulting in honey-combing the lower parts of piles and mattress binders, as also attacking the butt-ends of willows.

3. No worm-eating is found to exist on any material from the surface to a depth of five feet below. From this point it may extend to a distance of about eight inches below the bottom.

By the more liberal application of stone during the past two years, the willow work at the sea ends has generally been kept well covered, and has thus received a protection against the continuance of injury from the worms. Not much damage has come from that source during the low water seasons of 1877 and 1878.

In January of the present year, a board of officers appointed by the President, visited and examined the works. Touching this subject, the following is said in their report :

"The teredo does not attack wood where the free access of sea water is impeded. Those portions of a stick buried in mud or sand, or packed around with mud or sand, are secure. We have no reason to believe that the teredo has penetrated or can penetrate far into the interior of the mattress courses ; we have pretty good reason to believe that the founda-

tion matresses are and will remain secure; and probably also the bulk of the interior of the masses of willow work."

Quite recently an attempt was made to break off, at the extreme sea end of the West Jetty, some piles which were obstructing the palmetto work. These piles had been in place since March, 1877, and it was thought they could easily be broken off. But the inability of a powerful tug to do so, proved that the piles were still sound, and it was concluded to let them remain in place.

During severe storms or gales in the earlier stages of the work the superficial layers of mattresses suffered the greatest damage by being displaced, and thrown off, after the top of the jetties was dismantled of the stone that was placed there. The main object, therefore, to be gained from a consolidation of the lower ends of the jetties is to give them sufficient strength to resist such violent action of the waves.

Consolidation means compressive strength expended on solids and voids. It is evident that every tier of brush and every layer of stone in the jetties must have solids and voids.

At the upper part of the work the sand, mud, and clay of the Mississippi has been so firmly embedded in the meshes of the mattresses, and between the interstices of the stone, that very little additional compression is needed to make the work tight and permanent. But, as the jetties approach the sea end and come in contact with the clean salt water of the Gulf, experience showed that the sediment, which had accumulated between the willows and stones during a high stage, would speedily be removed during the subsequent low stage of the Mississippi. As a result the river sustained a considerable loss of water by leakage and overflow, where the volume was needed most, to serve the purposes of channel making.

It has been estimated by careful simultaneous gauging that nearly twenty-five per cent. was abstracted from the volume passing the Landsend at East Point, before it reached the mouth of the jetties. Of this loss the far greater part escaped through and over those portions of the jetties which extend beyond the sheltering protection of the reefs and shoals. It increased at the same ratio as the degree of exposure toward the sea ends, and it became evident that compression by weight would be the only cure for the evil.

While the efficiency of rubble stone for consolidating the upper parts

of the jetties could not be questioned, the requirements of weight and strength, sufficient to resist the shock of the waves at the sea ends, could not be obtained from the largest sized rock, which it was practicable to bring from the distant quarries.

About two years ago, as an experiment, quantities of large rock, weighing from one to two tons apiece, were, at considerable expense, placed upon the lower ends of the jetties. But in a severe gale, which occurred a few months later, these rocks were lifted up by the waves, rolled over the jetty embankment, and deposited on the leeward slope, thereby adding, per chance, to the strengh of that slope.

In selecting a material which would effectively consolidate the sea ends of the jetties, it was important to bear in mind that gales along the Gulf coast are generally attended by high flood tides which have been observed to rise from three to four feet above the level of ordinary tides ; these call into existence an enormous lifting power that can only be overcome by equipollent means of resistance.

For this reason, and in order to accomplish a permanent consolidation, something more powerful than quarried stone had to be resorted to. The plans of capping the last thirty-eight hundred feet of the East and twenty-eight hundred feet of the West Jetty, with blocks, made of cement concrete, provide for an application of from twenty-five to seventy-two tons in solid blocks. Their dimensions have been so chosen, as to impart great stability, and to dismiss at once all possibility of upsetting.

Cement concrete and lime concrete, have been largely used for important marine works at home and abroad. The Prussian harbors in the Baltic, the improvements of the French harbors of Toulon and Marseilles, the gigantic fortifications at Cherbourg, which were raised from a depth of twelve fathoms of water; again,the works of the harbor of refuge at Dover and the Island of Alderney, Great Britain, the foundations of many lighthouses, graving docks, break waters and sea dykes, parapets and fortifications, are constructed of blocks, formed by one method or the other, of cement or lime concrete.

Two more recent engineering works, those at the Sulina mouth of the Danube, and those at Port Said, the terminus of the Suez Canal, are being consolidated in a manner resembling the one now under progress of construction at the South Pass Jetties.

I am not aware, however, that in the history of any of these works, record is made of blocks weighing seventy-two tons.

General Gilmore, in his work on limes, hydraulic cements and mortars, speaks of "huge artificial blocks, capable by their inertia of resisting the waves of the Atlantic," used in the protection of the Cherbourg breakwater. These blocks weighed forty-four tons, and seem to be the largest on record. The same author also mentions the use of "immense blocks of concrete" at Marseilles, "for the protection of the outer or seaward slopes of the jetties, which enclose the basins and docks of that harbor. The concrete blocks weighed about twenty-two tons each."

The smallest blocks which are being put on the South Pass Jetties, weigh about twenty-five tons each, and the largest seventy-two tons each, not including the parapet, which is to be built on top.

In perfecting the plans, the protection of the blocks by slopes has been carefully considered.

Slopes are produced by gravity and friction, both forces acting upon the particles composing the slope.

In order that the particles may be at rest and resist separation, weight should be expended in amounts equal to the force represented by friction. Hence, at places exposed to the waves of the sea, the weight of the material used in the construction of a slope, should be equal to the force represented by the waves, and the slope will be safe with the degree of declivity due to the weight of the material.

But, if the slope be composed of less heavy particles it must be flattened, and the oblique surface enlarged, so as to increase the area which receives and meets the waves.

The plans for slopes now under progress of construction at the end of the jetties, may be said to fulfill part of both of these rules.

From the early beginning, the important part of slope construction, so highly essential for the preservation of the works, has received due and careful attention.

Single stones, in considerable quantities, have from time to time been used in protecting the lower parts of the jetties, but during heavy gales the sea has been observed to pick up these stones and carry them seaward by the receding action of the waves.

In this manner, the sea was slowly set at work, to build up a slope of its own, the surface area of which would be in conformity with the weight

of the stones and the friction of the waves upon them. A slope of unquestionable stability might have been obtained in this manner, and by continually adding fresh supplies of stone. But, such a process would have been slow and very costly.

The section of work, Plate XXXII, Fig. 3, shows that by the introduction of a sloping crib or cell-work, constructed of palmetto logs, great weight has been combined with abundant surface inclination.

The object of this mode of construction is to obtain compartments of moderate dimensions, by which to hold in place the stone and gravel, which is used to sink them.

The palmetto is a species of the palm tree, which grows in the tropics. Its wood is highly fibrous, tough and corky. The fibres are most intricately interwoven with each other, very tenacious and strong, causing rapid wear on the tools of the carpenter. Silicious matter has been found in the bark. The wood is said to be impervious to the attacks of the worm, and weighs about forty pounds to the cubic foot.

III.

Recent Constructions at the end of the Jetties.

The mode of constructing and depositing the concrete at the South Pass Jetties is novel in many respects, and, with the aim of contributing facts that may be of value, for the information and study of those interested in such matters, I have prepared the following notes on the two most important parts, now under construction at the sea ends, namely: the concrete work and the slope at the sea end.

1.—Concrete Work.

(A.) Preparatory Work, Machinery and Implements.

Both jetties have been treated in the same manner, both having received an independent and similar share of the preparatory and auxiliary work.

The plan on Plate XXXV represents the immediate surroundings of the concrete mixer on the east jetty, ten thousand two hundred feet below the Eastern Lands-end.

On account of the shoalness of the water near the jetty, and, in order to facilitate the transportation of the material from the barges to the

storage wharf, the latter has been connected by a bridge-portion sixty-three feet long, with the deeper water in the channel.

The storage wharf, bridge-portion and wharf-head are founded upon four hundred piles driven at intervals of eight feet, and connected with a 5 × 14 inches cap, for the support of the flooring.

The cement house occupies the northeastern portion of the storage platform. It is a low building, nearly square, and without windows. The roof is covered with felting, a layer of liquid pitch, and fine sea shells. The climate is damp, and these precautions were necessary for the preservation of the cement.

All the other ingredients, namely, sand, gravel and broken stone, are piled loose at different places on the platform, ready for immediate use.

The mixer or mill is placed over the jetty proper, and consists of a 5 feet 9 inches cube, made of quarter-inch boiler iron, well riveted and held together by bands of flat and T iron.

This cubical box is suspended by two hollow cast iron trunnions, seven and one-half inches in diameter, which are riveted from the inside of the box to two diagonal corners opposite each other, and rest in a tower or frame work substantially built of heavy timber. The centre of the trunnion is twenty-two feet above average flood tide, and the mixer is revolved by a steam engine which stands on the wharf below.

The two views on Plates XXXVI and XXXVII, together with the plan on Plate XXXV, will materially aid in understanding this partly novel machinery.

It will be seen that the cubical box has been cut off horizontally on one of the corners, so as to obtain a triangular opening for admitting and discharging the material. A cover (*D*, plates XXXVI and XXXVII) is made of the severed portion, and a small hand crane is provided by which it can be lifted and shifted.

As the mixer has to be opened and shut once for each charge of concrete it is a matter of consequence to have the manipulation proceed as rapidly as possible. The method employed has worked satisfactorily.

When the mixer is filled it is closed by sliding the cover under the four clasps or lips, which may be seen on the drawing, and at once secured by four point screws. The hinged screws (*ss*) are then righted up and screwed with their nuts down.

To allow the rapid working of these six screws long handles have been attached to their upper ends.

The water enters the box through the hollow journal at (*B*, *B*) while the ingredients are being revolved. The tank (*C*) which supplies the water stands on the top platform and has a floating gauge attached to it which is watched by the man whose duty it is to shut the valve (*A*) when the requisite quantity of water is admitted. The engine in its turn fills the tank.

For the transportation of the dry material from the wharf to the opening in the mixer, and the lift of nearly forty feet in hight necessarily included in the operation, a steam elevator forty-two feet high has been erected on the river side, and close to the mixer.

Hand carts, constructed for this purpose, as an improvement on wheelbarrows, are used for conveying the ingredients to the elevator box (*EE*), where they are deposited in different layers alternately. The elevator box is of wood, lined with sheet iron, measuring 6¼x5¼x4 feet, with sloping bottom, and trap door facing toward the mixer. It is guided by cleats, which project between the vertical leaders (*FF*), and ascends until the bottom reaches the trough (*HH*), when the trap door is opened and the contents turned into the mixing cube. The trough, which guides the material, is also lined with sheet iron, and is kept covered.

The revolutions of the mixer to each charge number twenty-two; the time required is about two minutes and twenty seconds, which is sufficient to thoroughly incorporate the ingredients.

From the drawings it will be seen that a railroad track has been laid to facilitate the quick deposit of the concrete. This track follows the centre line of each jetty, and extends up and down stream from the mixer station sixteen hundred feet seaward and twenty-two hundred feet landward. A branch track on the sea side has also been built for a distance of three hundred feet, at the extreme sea end, to aid in the construction of the sea slope.

The top of the rail at the mixer is ten feet above average flood tide, and at the sea end it is seven and one-half feet above that plane, the descending grade being chosen to be of advantage when the cars leave the mixer with a load of concrete.

The bents are eight feet apart, each composed of two cypress piles of sixteen inches diameter at the butt end, driven through the cone of the

jetty. A 5x14 inches cap is set on edge and drift-bolted to the piles, and 6x8 inches stringers are laid in the line of the track for the support of the rail.

The piles in each bent are driven as close together as the width of the concrete block designated for the place permits. A few feet are generally added to allow for the placing of the moulds. Towards the sea end the bents have been well stiffened by diagonal braces and bearings.

The track above the mixer station is mounted on trestle work, the bents being 8 feet apart, as in the case where piles are used.

The "rolling stock" of this railroad consists, for each jetty, of one locomotive and one concrete dumping car (see illustrations, Plates XXXVI and XXXVII). The locomotive is set upon a truck, which was originally intended to be used for a second concrete car when it was expected to run the cars by hand.

But, under the necessity of more rapid means of conveyance, the demand for a locomotive became soon apparent. The one illustrated is constructed almost entirely of old scraps, such as will collect in the shops of large works. It is propelled by an ordinary rotary engine, and has been extremely useful.

The cars used for the dumping of the concrete were made by the same firm who contracted for the mixers (Pusey, Jones & Co., of Wilmington, Del.). They are 6½ feet long, 4 feet wide, and 3 feet 3 inches deep, and made to contain about two cubic yards. They are strongly built, of quarter-inch boiler iron, and mounted 9 inches below their centre of gravity, on an iron axle 3 inches in diameter, which is riveted by a round plate to both ends of the car. With the help of two ratchet wheels and wooden levers permanently attached to the axle on each end of the car, the dumping of nearly 9 000 pounds of concrete is done almost automatically, and the car is easily turned back to its upright position by two men (see Plate XXXVI).

Special attention might be called to additional details of interest, but their discussion would occupy too much space. The drawings on Plates XXXVI and XXXVII show the mechanism of the work so as to be easily understood.

(B.) Method of Placing the Concrete.

The operations involved in this method are as follows :

1. The preparing of a level bed.

2. The placing of the moulds.
3. The conveying and discharging of the concrete.
4. The removal of the moulds and protection of the sides by stone.

A level and solid bed is one of the chief requirements for the successful formation of the concrete blocks.

A gang of men is detailed for this purpose, and equipped with shovels, picks and crowbars. They commence by first removing the larger rock from the top of the jetty, and throwing it over on the river or sea side, wherever it seems to be of most advantage.

Small flats with gravel and broken stone are then moored alongside, and the contents wheeled or thrown with shovels on the embankment, there to be distributed and leveled. Pains are taken to thoroughly incorporate the gravel and small stone with the willows of the old mattresses. The foreman is provided with a gauge staff, by which he is enabled, referring to the railroad track, to bring the surface of the jetty to a uniform level.

When the weather is rough, which is by no means a rare occurrence, the material is brought by cars from the storage platform at the mixer station, and dumped wherever it is needed.

The placing of the "moulds" is next in order.

The moulds are wooden boxes, whose inside dimensions correspond with the size of the blocks. Plate XXXVIII, Figs. 1, 2, 3 show details of a mould for the formation of a block twenty feet long, twelve feet wide and three and one-half feet thick. The moulds are composed of a thin flooring and uprights or stanchions, which are so fixed that they will hold the sidings in place temporarily until the concrete has hardened. To this end, inch boards are spread longitudinally on the jetty where the blocks are already finished. Cross ties or battens *(a, a, a)*, of 2×6 inches lumber are nailed to the flooring at intervals of four feet. Two uprights or stanchions *(b, b)*, are then put up in the center of the two end ties, opposite each other, and pieces of two inch plank *(c, c)*, twelve feet long, permanently nailed to them and raised to the proper hight three and a half feet above the flooring. The twelve stanchions *(d, d)*, are set next at right angle to the flooring, twelve feet four inches in the clear, there being always two for each cross tie. These stanchions are held at the lower end by a dove-tailed piece of square lumber *(e)*, nailed to the ties outside, and facing a corresponding notch on the outer side of each stan-

chion. The sidings, consisting of two inch planks, twenty feet four inches long, provided in each end with clamp hooks of one inch strap iron, are then set on the inside of the line of stanchions *(d, d)*, the hooks clamping the end sidings. (*See* end elevation, Fig. 2.)

The top planks *(f, f)*; on both ends, being fifteen feet long, are so placed that they project one and a half feet out on each side. They have two notches *(g, g)*, nine inches wide and one and a half inches deep, at the upper edge, for the reception of a stiffening plank *(h, h)*, with two iron clamp hooks on each end to clasp the siding at the edge. Wedges *(k, k)*, are used to hold the plank in position.

These moulds, constructed almost entirely without nails or spikes, are sawed out in parts and fitted by carpenters, and carried on trucks over the finished blocks forward to the place where they are needed. Here the flooring is laid down on the jetty, and the other parts are then quickly put in place.

It will be noticed that all the stanchions are on the outside of the box excepting the two at each end. These are inside, in order to permit the placing of the blocks within a few inches of each other.

As a rule every mould is pushed up close to the finished block above, and its position is verified by referring to the center of the railroad track.

The filling of the mould with concrete may begin immediately after this. The carpenters return with their empty truck, the men who level up the jetty proceed down stream, and the masons take their places in the mould to attend to the concrete as it is being deposited.

The concrete is made in single charges, measuring two cubic yards each. Each charge as soon as deposited in the car under the mixer, is taken without delay to the place where it is to be dumped. The time consumed in the transfer varies, of course, with the distance. But the speed allowed to the engine, being about twelve miles per hour, seldom more than one minute of time will be consumed in the run between the stations. The train stops directly over the mould, the two men on the front and rear platform release the pawls, which hold the ratchet wheels, and the concrete is dumped into the box.

The total time required for the transportation of the material contained in one charge, from the different depots to the moulds on the jetty, has been ascertained to be as follows :

	Min.	Sec.
1. From wharf to elevator box	7	55
2. From elevator box to mixer	3	43
3. From mixer to car	4	27
4. From station to station	1	00
5. From car into moulds		30
Total	17	35

The hand labor is so regulated as very nearly to balance the functions of the engine, and, in this manner, only fifty per cent. of the time required is really consumed, so that about nine minutes are required to make and place two cubic yards of concrete, or one hundred and twenty-three cubic yards in one day of ten working hours.

It should not be inferred, however, that this is an average of the daily work done. There are days when rapid progress will be unavoidably delayed by rough weather, or during extreme high water at spring tides. In such cases, the placing of the mould boxes is seriously impeded, and, in consequence, the mixer cannot be worked to as great advantage. One hundred cubic yards of concrete is a fair daily average on one jetty.

During the earlier part of construction, the concrete was rammed by masons in the moulds. But, of late, this process has been entirely abandoned, as it has been found that the vertical fall of from ten to twelve feet, from the car into the mould, leaves the particles in a far better state of compression than could be obtained through ramming.

The concrete, after being deposited, is stirred as little as possible and only shifted, while it is quite fresh, to fill up irregularities and keep the layers approximately level and parallel.

When the top of a mould is reached, the surface of the concrete is roughly leveled with a rake, and allowed to set without further disturbance. Another mould is then commenced, filled, and so on, one after another, according to the plans.

Four days after the setting has commenced, each block is coated on the surface with a plastering of mortar, composed of fifty per cent. by volume of American Portland cement, and fifty per cent. of sand. The depth at which this mortar is laid may vary from one to three inches. It is applied with the trowel, and all joints between the stones, and other irregularities that may exist on the surface, and near the edge of the mould, are well filled and smoothed off. The mortar is prepared in small

quantities, and the plastering done quickly. The box is finally covered with inch boards, and not disturbed again for two weeks. During that time, the sea and river side of the blocks are protected by a revetment of rubble stone.

At the end of two weeks, the concrete has become fully hard enough to allow the removal of the moulds. The wedges (*k*, *k*), Plate XXXVIII. Fig. 1, are then pulled out, the stiffening planks (*h*, *h*) removed, and the stanchions (*d*, *d*) and longitudinal sidings taken away.

The stanchions (*b*) and sidings (*c*), which rest close between two blocks, are left until some future day, when they may be removed, and the small interval filled out with mortar or rubble masonry.

(C.) Notes on Ingredients composing the Concrete.

The concrete is made of broken stone, gravel, sand and cement. The broken or McAdam stone is quite irregular in shape, being broken by hand. The size is specified in the contract, each of the stones is to pass through a ring, three inches in diameter.

The gravel is brought from Prophets Island, near Baton Rouge, La., a distance of two hundred and fifty miles above the jetties. It is obtained from the deposits at the mouth of a creek, which empties into the Mississippi, and is raised from the bottom by dredging. The pebbles vary in size from one-thirtieth of an inch to two and a half inches in diameter. The sand is delivered by schooners, and comes from the islands in the Mississippi Sound, near the mouth of Pearl River, Miss. It is a moderately coarse and sharp grained sand of white or pale yellowish color, the diameter of grains averaging about one-fortieth of an inch. It is dug up in a state of humidity, from a depth of several feet below the surface, and used as fast as it can be delivered at the works.

It may be stated that the quality of the sand, which is found in the more direct neighborhood of the delta, and on the reefs adjacent to the jetties, is not deemed suitable for the purpose of concrete making, as it is chiefly composed of fine and round particles of silicious nature, rarely exceeding one-seventieth of an inch in diameter.

In the table below may be found the percentage by volume of voids, and the weight per cubic foot, of the stone, gravel and sand, used in the concrete.

Material.	Percentage by volume of voids.	Weight per Cubic foot.
Broken Stone	.489	79.50 lbs.
Clean Gravel	.314	119.24 "
Sand	.333	79.72 "

The cement, which is employed at these works, is Saylors' American Portland cement, over five thousand barrels of which have been used to date. Careful tests, which have been made with it, have justified Mr. Eads in further recommending its use. The following table, condensed from numerous daily tests, and grouped, to save space, in the order of months, exhibits the results obtained from the tests of this cement. The testing is done on fineness, weight and tensile strength in conformity with the specifications of the contract, and in a careful manner.

For testing of tensile strength, a Riehle counter balance testing machine is employed. The briquettes represent an area of two and a quarter square inches in the section, but they are sufficiently enlarged on both ends, for the application of the clamps.

Condensed Table of Cement Tests—S. P. Jetties.

Month—1879.	Number of tests from which average is taken.	Seven day test, average tensile strength in lbs. per sq. inch of neat cement.	Percentage passing sieve, 2 500 meshes to sq. inch.	Weight per U. S. struck bushel in lbs.
February	155	285 lbs.	84	117.60
March	157	262 lbs.	87½	123.00
April	271	288 lbs.	84½	121.00
Average Result	583	278 3/10 lbs.	85 3/10	120.53 lbs.

The cement is shipped from New York by steamer to New Orleans, and thence on barges to the store houses at the jetties.

Considering the damage to cement, which often results from transhipment by sea, the tests of three months at the jetties, are all the more satisfactory.

Saylors' Portland cement is a slow setting cement, which may be moderately restirred and shifted, without destroying its hydraulicity.

The market weight of a barrel of this cement is 380 lbs., or 133.33 lbs. per cubic foot. When gauged in this state of compactness, with $\frac{1}{3}$ measure of water, the paste will expand, so as to occupy 3.9 per cent. in excess of the volume originally occupied.

When piled loose, so as to weigh eighty-nine and a half pounds per cubic foot, and gauged neat, with enough water to make a paste of similar consistency, the latter will shrink until it occupies 80.7 per cent. of the volume originally occupied.

These deductions were important, in deciding upon the proportional parts of ingredients composing the concrete.

Minor points may have been changed, but essentially, the proportional parts have remained as follows :

15 parts	by volume	of	broken stone.
4.38 parts	"	"	gravel.
8.28 parts	"	"	Sand.
3.00 parts	"	"	cement (barrel weight).

It should be stated that the gravel in this estimate is clean gravel, referring only to those particles, which are rejected by a seive having three hundred and twenty-four meshes to the square inch. Thirty-eight per cent. by volume of the gravel, delivered at the works, will pass through such a sieve.

From this, and with the coefficients of voids, the net contents of one hundred cubic feet of set concrete, may be computed as follows :

1. Broken stone,	80.75	cub. yds.,	which gave	41.26	cub. yds.	of solids.
2. Clean gravel,	23.58	"	"	16.17	"	"
3. Sand,	44.57	"	"	29.73	"	"
4. Cement,	16.15	plus expansion	"	16.78	"	"
	165.05	cub. yds. of dry material make		103.94	c. yds.	of concrete.

From this the coefficient of shrinkage may be obtained :

$$S = \frac{103.94}{165.05} = 0.629.$$

The excess of 3.94 cubic yards is consumed in the final induration of the concrete. The figures have been computed from careful observations, and may be relied upon.

The ingredients are mixed with fresh water, in quantity equal to about ten and a half per cent. of the volume of the dry material. The amount is registered on the gauge.

(D.) Present Condition of Work and Observations on Concrete Blocks.

TABULAR STATEMENT SHOWING PRESENT CONDITION OF CONCRETE WORK, SOUTH PASS JETTIES.

	EAST JETTY.	WEST JETTY.
Total length of concrete in lineal feet, proposed to be laid	3 800 feet.	2 800 feet.
In place June 11th, 1879	2 097 "	2 324 "
Balance remaining, in lineal feet	1 703 "	476 "
Total amount of concrete, in cubic yards, proposed to be laid, including parapet	3 735 cubic yards.	3 087 cubic yards.
In place June 11th, 1879	2 071 " "	1 899 " "
Balance remaining, in cubic yards	1 664 " "	1 188 " "

By far the greater and most difficult part of the concrete work is already in place. On the East Jetty the lowest block is within one hundred and sixty-seven feet of the extreme sea end, and on the West Jetty, the blocks have approached the end to within four hundred and seventy-six feet.

Operations are now chiefly confined to the upper end, where the smaller width of the blocks allows the work to proceed at the rate of one hundred and twenty lineal feet daily.

The weight of the concrete has been ascertained by actual test, and by computing the weight from the different dry ingredients, as follows :

Concrete green..... 160 lbs. per cubic foot.
" thoroughly dry..... 149 lbs. " " "

The blocks, after removing the moulds, expose, generally, a uniform and smooth surface. Irregular places and holes are plastered by the masons.

In regard to the construction of the parapet, it has not been decided yet, when it will be time to commence. The degree of subsidence displayed by the blocks will settle this point in course of time.

At present it may be too early, from the limited amount of observations, to discuss the probabilities involved in this question. It is clear, however, that the amount of compression, exacted by the tremendous weight of the blocks, will continue to act upon the elasticity of the subaqueous layers of mattresses, until the same is ultimately destroyed.

A complete record, ascertained by careful and frequent periodical levelings, is kept of each block, and the elevations are compared with the original plane, at which the blocks were set.

There seems to be a general tendency, on the part of the blocks, to settle within the first ten days of their construction, and then to remain stationary or nearly so for an indefinite period.

The impetus imparted by the sudden application of so great a weight is evidently the cause of this action.

The subjoined tables are given to further illustrate this subject:

TABLE 1.

SHOWING SUBSIDENCE OF CONCRETE BLOCKS, AT DIFFERENT PERIODS, ON EAST JETTY.

Number of contiguous Blocks from which average is taken.	Net Weight of mass of Concrete under consideration, in tons of 2 000 lbs.	Initial Elevation of top of blocks above av'ge flood tide.	Date when placed.	Date when levels were taken.	Elevation above A. F. Tide at those dates.	Elevation above A. F. Tide on June 11th.
	Tons.	Feet.			Feet.	Feet.
4	110	3.00	Feb. 2.	Feb. 10.	2.685	2.480
4	136	3.00	" 12.	" 20.	2.440	2.140
4	136	3.00	" 18.	" 20.	2.790	2.600
4	150	3.00	" 24.	Mar. 4.	2.605	2.415
4	150	3.00	Mar. 4.	" 14.	2.610	2.406
4	193	3.50	" 8.	" 14.	3.351	3.150
4	193	3.50	" 11.	" 25.	3.440	3.328
4	288	3.75	" 15.	" 25.	3.533	3.373

TABLE 2.

SHOWING SUBSIDENCE OF CONCRETE BLOCKS, AT DIFFERENT PERIODS, ON WEST JETTY.

Number of contiguous Blocks from which average is taken.	Net Weight of mass of Concrete under consideration, in tons of 2 000 lbs.	Initial Elevation of top of blocks above av'ge flood tide.	Date when placed.	Date when levels were taken.	Elevation above A. F. Tide at those dates.	Elevation above A. F. Tide on June 11th.
	Tons.	Feet.			Feet.	Feet.
4	110	3.00	Mar. 21.	Mar. 24.	2.912	2.854
4	110	3.00	" 24.	Apr. 7.	2.930	2.785
4	136	3.50	" 27.	" 7.	3.262	3.131
4	136	3.50	" 29.	" 7.	3.200	2.981
4	136	3.50	Apr. 1.	" 7.	3.410	3.041
4	150	3.50	" 6.	" 18.	3.420	3.343
4	150	3.50	" 8.	" 18.	3.130	3.083

2.—SLOPES AT THE SEA END.

The construction of the sea and river slope by palmetto crib work, as proposed for the lowest six hundred feet of the jetties, was not commenced before the month of April of the present year. Plate XXXVIII, Figs. 4 and 5, represent a sloping crib, fifty feet long, twenty-two feet wide, and five and a half feet high, intended for shoal water.

Before the dimensions of a crib are given to the carpenters, a careful investigation is made, embracing depth of water and condition of bottom, on and near the place where the crib is to be placed. Referring to the one on the drawing, there are fifty-one palmetto piles (*A*, *A*, see Figs. 4 and 5), each twenty-two feet long, which are placed in one row, one foot from centre to centre, on the inclined ways, formerly used for mattress building.

This being the floor of the crib, a second row, consisting of five logs (*B*), is placed to break joints with the flooring, at distances of five feet from centre to centre. In the same manner the third row is placed, consisting of eleven piles, sixteen and a half feet long, at distances of five feet between the centres, and breaking joints with the lower row.

Augur holes are then bored, and the rows bolted to each other by one inch bolts. The fourth and fifth row of piles is then laid, as shown on the illustration, and drift-bolted to the lower layers.

The crib is braced by short logs (*C, C*), standing upright against the corners of a cell. Their lower ends are flattened, and wedged tight between the flooring, where they are fastened by bolts.

In addition to this, stirrup bolts are used at every alternate corner of a compartment, which tie all the logs from the bottom to the top.

The compartments are four feet square in the clear, and large enough to admit the largest bowlders that are brought to the jetties.

The cribs are pulled off the ways and into the river by a tug, which takes them at once to the place for which they are built.

Here a row of guide piles has been driven, about ten feet from the jetty embankment, to which the vertical edge of the crib is lashed. The sinking may then take place. The compartments are finally closed by immense bowlders, which are lifted into position by a derrick.

The remaining space of about ten feet in width, between the vertical edge of the crib and the jetty embankment, is filled with stone until it appears above water.

At some of the cribs the flooring has been constructed of palmetto logs, split lengthwise through the centre, but it is quite immaterial to the strength of the crib; besides, the labor involved in cleaving the logs, hardly justifying its constant application, it was only resorted to when the supplies ran short.

APPENDIX A.

Explanatory Remarks on the Chart of Jetty Channel, Plate XXXIX.

The soundings are made by the United States Engineers. In the earlier stages of the work they were made once a month; now a complete channel survey is made only four times a year.

The chart on Plate XXXIX has been so arranged as to be nearly self-explanatory. The figures enclosed in circles denote the depths in May, 1875, all the others the depths to-day.

From the comparison, we ascertain one positive fact, namely: That the depth on South Pass bar has increased from nine and two-tenth feet,* to twenty-seven and two-tenth feet. This is the result of four years work.

---

* Although depth of 9.2 feet is shown on the United States Coast Survey Charts of May, 1875, we found it impossible to get our tug boats, drawing only seven feet, over the bar, before our works had made any impression upon it. For this reason, Mr. Eads very properly claims that the maximum depth on the bar was not more than eight feet when the work was commenced.

All matters relating to the regimen of the river, the general principles upon which the construction of the jetties was based, the numerous interesting phenomena connected with these works, and, above all, the surprising changes in the Gulf bottom, beyond the end of the jetties, have been exhaustively treated by Mr. Corthell, member of the Society, in his paper, read a year ago.

It may simply be added, that after having arrived at the end of another year, and produced new and valuable results, the arguments become doubly strong.

The chart presented a year ago, indicated that there was a navigable channel of twenty-two feet over the bar. The increase in navigable depth during the past year has been, therefore, five and two-tenth feet, with corresponding ameliorations in the channel above. Still, the past year has been comparatively short in regard to work.

The epidemic, which raged in the South, made it necessary to suspend the works temporarily. This suspension lasted four months, and was complete, nothing was done toward maintaining the works. In their unfinished condition, they were left, as it were, to take care of themselves, embracing in that period two of the stormiest months in the year—September and October.

In my personal intercourse with members, interested in this improvement, the opinion has been expressed, that the suspension of the works would entitle the last year to be called a test year.

This opinion seems just, and the reports giving channel depths, made directly after work was resumed, at the end of November, were looked upon with more than usual interest. It is safe to say that these reports showed no deterioration. The first official survey, made by Captain M. R. Brown, Corps of Engineers, U. S. A., the United States Inspecting Officer, showed on December 6th, 1878, a navigable channel of twenty-three feet depth, while on July 15th, it was only twenty-two feet.

The gradual increase of depth on the bar, since the commencement of the works, is given in the following table :

Date.	Navigable Depth in Feet Below A. F. T.*	Date.	Navigable Depth in Feet Below A. F. T.*
May, 1875.....	9.2	October, 1877.....	21.0
January, 1876.....	11.0	January, 1878....	23.0
April, 1876.....	17.0	April, 1878.....	23.0
July, 1876.....	20.0	July, 1878.....	22.3
October, 1876.....	20.3	October, 1878.....	23.0
January, 1877....	20.8	January, 1879....	23.9
April. 1877.....	20.9	April, 1879.... ...	27.2
July, 1877.....	20.3		

* A. F. T—abbreviation of Average Flood Tide.

It will be observed that the improvement has been a progressive one, generally, although retardations and fluctuations, in the formation of the channel, have not been uncommon.

In the preceding pages of this paper, the trouble which was experienced in protecting the sea ends of the jetties has been referred to, as also the loss which resulted from considerable portions of the volume being withdrawn when its energy was needed most. Connecting these incidents with the sudden and marked deepening which occurred between the months of January and April, 1879, while the concrete blocks were being placed, it is but proper to accredit the greater share of the retarding and fluctuating influences at former periods to causes directly connected with the loss of volume.

Detailed statements of events which followed the cure of the evil will therefore be regarded with interest.

The following table gives the relation between the progress of the concrete work and the channel scour :

Date. 1879.	Terminus of Concrete measured Seaward from East Point, in feet.		Lineal feet of Concrete in place.		Navigable Depth on Bar, in feet.
	East Jetty.	West Jetty.	East Jetty.	West Jetty.	
	Feet.	Feet.	Feet.	Feet.	Feet.
Jan. 20..	10 474		382		23.9
Feb. 13..	10 798	10 372	706	240	23.9
March 14..	11 511	10 372	1 419	240	24.8
" 27..	11 633	10 680	1 541	548	26.7
April 8..	11 633	11 202	1 541	1 070	27.2

In addition to the many phenomena developed in the construction of these works there is still one which I believe has never been alluded to before. I refer to the conspicuous turn which the channel makes in emerging from its confinement between the jetties.

This turn is in an easterly direction, and has never been marked more prominently that at the present moment. It engages at once our most attentive consideration.

During the earlier stages of bar erosion the tendency of forcing an outlet in an easterly direction was but feebly marked. The section of the channel at the jetty ends was almost uniformly flat, resulting from the incomplete condition of the jetties and the struggle of the current to reach the level of the Gulf in every possible direction. Still, the slight depression which existed to mark the width of the channel, even at that time, was located on the eastern half of the section.

It seems difficult, consulting the records of our observations, to find positive assurance for an explanation of the phenomena of this eastern outlet.

At a place so full of the exhibits of unexplored elements the experience which four years represent is but meagre and incomplete.

The reasons *pro* and *con.* are many on both sides, and while it might be plain to the minds of some that the phenomenon is caused by the sudden relief of the volume under head, others might claim that the condition of the bottom on the east side was such as to hasten scour. But, although both may have their share, the main point toward a reasonable solution of the problem seems to rest in the fact that the prevailing winds, the tides, and salt water currents approach the jetty mouth from an easterly direction, and that the relation existing between these forces causes the salt water to continually pass under and encroach upon the fresh water which the pass discharges in flood stages of the river, thereby crowding and deflecting the lower stratas, with their heavier ratio of sediment, over to the west side of the mouth.

In support of this supposition, it may be stated that observations at every high stage of the river have shown the depths over the western area to have diminished, while, at low river, when the salt water has unobstructed admittance to the mouth, the depths increase from causes that cannot justly be attributed to any scouring power due to the jetties.

In addition to this, it can be stated that at the end of every low river the depths on the west side have increased over those of the previous year at the same ratio as they have increased in the channel, and thoughtful reflection will point at once to the indefinite period which must elapse before the often raised question of extending the jetties seaward will demand serious consideration.

Such are the conditions as existing to-day.

A year ago conclusions of equal importance were arrived at. The intervening time has brought forward additional proofs in confirmation of the arguments used, and, while we are reviewing the past and prognosticating the future of the works, the ships of all nations, laden to their utmost capacity with the various products of the Mississippi Valley, bear witness to what has been accomplished.

APPENDIX B.

Explanatory Remarks on the Chart of the Head of the Passes, Plate XL.

The extensive system of dams and dykes, which is built at the head of the passes, exhibited on Plate XL, is the result of the gradual solution of a problem which is conceded to have been far more complicated in its details than any of those which presented themselves at the mouth of the river.

The head of the three passes of the Mississippi is about twelve miles above the mouth of the jetties. The Mississippi, in approaching this point from above, gradually widens from twenty-six hundred feet to eight

thousand five hundred feet, where the river divides into the three passes.

As a result of this widening there existed at this point a shoal, common to all the passes, which extended from one shore of the Mississippi to the other. The depths on this shoal were proportionate to the size of the pass at whose head it was located. Thus South Pass, being the smallest, discharging only about ten per cent. of the volume of the Mississippi, had the shoalest entrance, the depth, that could be carried into the pass, being not over fourteen feet.

In the table on the next page may be found the chronological history of the works constructed for the improvement of this shoal.

The original design for the improvement of the head of the pass contemplated the closure of the Western Channel alongside of the Island which divides the entrance into the Pass at its upper end. But, by reference to the map (on Plate XL), it will be seen that the channel, which is now the highway of commerce, instead of lying to the east of the island, is located on its western side. The causes which led to this radical change of design constitute one of the most curious and interesting portions of the history of this work.

It was believed that the construction of the East Dyke alone would increase the depth of water at the head of the pass to such a degree as to avoid all question of the right of Mr. Eads to receive his first payment of $500 000 from the Government. This payment was to be made after securing twenty feet in depth through the channel at the mouth of the pass. His obligations to deepen the shoal at the head of the pass were not clearly defined, and the difficulty in raising money to carry on the work in the face of the doubts and opposition which the enterprise elicited made it of the first importance that no more means should be expended at the head of the pass than was absolutely necessary. It was believed that no further works at that locality would be needed until after the receipt of the first Government instalment.

At that period of time the channel through the jetties had developed so far as to justify the announcement by Mr. Eads that it was navigable for vessels of sixteen feet. This was denied by the opponents of the work, who asserted that a channel of barely twelve feet in depth existed. The United States inspecting officer was, therefore, instructed by the Secretary of War to measure the depth of channel, and give an official certification of the same, to correct the misrepresentations which were at the time seriously interfering with the negotiations for money with which to prosecute the work. At the same time it was claimed that material washed out from the Jetty Channel was reforming a bar immediately in front of the jetties.

A survey made about this time by the United States Coast Survey disproved this latter statement. A few days after, the Cromwell steamship *Hudson* entered the Pass without any difficulty, drawing over fourteen

TABLE,

Giving Record of Dates relating to the Construction of the Works at the Head of the Passes

No.	Name of Dam or Dyke.	Date when Commenced.	Date when Finished.	REMARKS.
1	East Dyke	Dec. 19, 1875	May 17, 1876	
2	Dam 1	July 19, 1876	Aug. 21, 1876	
3	Lighthouse Dam	Aug. 23, 1876	Sept. 6, 1876	
4	Island Dyke, from Point P. to New Cluster	Sept. 6, 1876	Oct. 26, 1876	Torn down April 10, 1877; rebuilt on Line P. R., between March 12th and April 17, 1879.
5	Lighthouse Dyke	Sept. 16, 1876	March 17, 1879	Was gradually pushed up stream by extensions, January 20, 1877, March 2, 1877, May 30, 1877, and March 17, 1879.
6	South West Pass Sill	Sept. 18, 1876	Jan. 31, 1879	The foundation was in place on November 6, 1876, and the second, third, and fourth tiers were laid between December 9, 1878, and January 31, 1879.
7	West Dyke	Sept. 18, 1876	Dec. —, 1878	
8	Island Dam	Jan. 25, 1877	Feb. 13, 1877	
9	Island Dyke, from Island to Point P.	Feb. 3, 1877	April 5, 1879	The foundation was in place on February 13, 1877.
10	Pass A L'Outre Sill	March 21, 1877	May 8, 1877	
11	Upper Dam	April 2, 1879	June 4, 1879	
12	Island Dyke, from R. to T.	.....	.....	Under progress of construction.

feet; and a few days later a ship of the same line went out through the Jetty Channel drawing about sixteen feet.

The subsequent use of this channel by this line of steamers furnished for several weeks the only undoubted evidence which Mr. Eads was able to obtain of the remarkable improvement which had been to that date effected. But it was deemed absolutely necessary to increase the depth over the shoal at the head of the pass, to keep pace with the deepening through the jetties; and, in this regard, it was found that the East Dyke had not produced the effects which had been anticipated. The retarding influence which it exerted upon the natural flow of the water created a head above it, and this caused, in the course of a few weeks, as large a flow into Pass A L'Outre as had existed before the construction of the dykes although the direction of the dyke placed its upper extremity six hundred feet to the eastward of the neutral axis of the current between South Pass and Pass A L'Outre. The reduced current below the head of the dyke, and to the west of it, caused a large amount of deposit to be thrown down, to the injury of the eastern entrance to the pass, while the western entrance had increased in depth about two feet.

To carry out the original plan, therefore, it would have been absolutely necessary to construct the dam between the island and the western shore of the pass, and to do this would temporarily have stopped the Cromwell steamers from the use of the jetties altogether. For this reason it was determined to change the plan and treat the western entrance in a manner similar to that which was designed to be applied to the eastern one, and accordingly the Eastern Channel was closed by "Island Dam," and the outlines of the present channel, on the western side, were fixed by the location of the dykes on that side, as shown on Plate XL.

The construction of the East Dyke developed the important fact that it was simply impossible to construct any works by which the flow into South Pass could be concentrated without having the resultant head of water raised by such works, no matter how insignificant the elevation might be, tend to increase the flow into one or the other, or both of the great passes, at the expense of the smaller one. To prevent the enlargement of these passes, which was sure to ensue, as the first effect of such works, it became necessary to sill each of these great passes.

The mattress sills, which extend across the two great adjoining passes, the Southwest Pass and the Pass A L'Outre, connect the system of works with the east and west shore of the Mississippi. These sills are simply submerged dams.

It should be stated that the Pass A L'Outre sill was not sunk until after considerable scour had taken place, under the influence of contracting that pass by the East Dyke, and that scour had also been observed on the eastern part of the Southwest Pass before it was silled.

A complete display of the effects of all the works constructed since December, 1875, is made by the areas of scour and deposit, which are exhibited on Plate XL.

The gradation on the fills is made in vertical offsets of five feet. The blank spaces denote scour, the amount being inserted in feet and tenths of feet. The neutral areas on which there has been no scour and no deposit are expressed by one faint tint.

With the aid of these explanations, a brief study of the chart will clearly reveal the causes by which erosive power was obtained. They can be traced back to the increase of velocity, resulting from the head of water which was obtained above the line of the works.

Again, the closing and filling up of one of the two entrance channels of the South Pass, and the corresponding enlargement of the other, the encroachment of the current upon the western shore-line of the new channel, and the increase in the width of section resulting therefrom, all these points are plainly elucidated on the chart, and indicate that South Pass is most actively engaged in the efforts to regain its original section.

In briefly reviewing the work doné at the head of the passes during the last year we may state that,

1st. The Lighthouse Dyke has been extended up-stream a distance of two hundred and eighty feet, thereby throwing the effects of concentration within three hundred feet of the twenty-six foot contour of the Mississippi.

2nd. The Southwest Pass sill has been raised in the following manner :

Two	tiers	of	mattresses,	to	a point	1 855	feet	from	west	shore.
Three	"	"	"	"	"	1 785	"	"	"	"
Four	"	"	"	"	"	790	"	"	"	"

Thence the sill has been brought gradually to the surface, which is reached at the east end of West Dyke, four hundred and seventy-five feet from the west shore.

In this manner the area of Southwest Pass is permanently decreased to eighty and a half per cent. of its original size. The obstruction placed in the way of the current, although twenty-five feet below the surface, is clearly distinguished by the break in the current at the surface, and the smooth water above the sill.

Judging from experience elsewhere, it is quite probable that in the course of time sediment will be deposited above the sill, and that the bed of the pass will be permanently fixed at the hight of the mattress work.

The result of such an event, on the permanence of the deep channel into South Pass, cannot be questioned.

3d. The island dyke has been raised to the surface from the head of the island up stream to point *P*. This work was done with a view of protecting the channel from sediment, which, in cases of easterly winds, was carried from the soft mud flats, east of the dyke, and borne toward the channel.

4th. The island dyke has also been built on line *P.*—*R.* Originally it extended from point *P.* to New Cluster; but this part was torn down

in April, 1877, in order to restore the loss of volume, which South Pass had suffered as one of the temporary effects of choking its entrance to procure concentration.

The new direction, which deviates slightly from the original location, lies more in the thread of the current, and was selected to prevent the formation of an eddy on the west side of the dyke.

The original dyke was built in a temporary manner, by tilting mattresses and suspending them vertically against a row of piles. The new dyke is built up strongly by horizontal layers of mattresses.

5th. The "Upper Dam" is a recent addition to the system of works. It was designed with a view of increasing the depth into South Pass from twenty-four and a half feet (the present depth) to twenty-six feet; but it will also tend to restore to South Pass the orignal volume of 1875. The curved extension of the Island Dyke to point *T*, as shown in the broken line on the chart, is an auxiliary design, serving the same purpose.

I was in hopes of being enabled to show a more marked area of scour in the line of the new current, which is deflected from the west end of Upper Dam into the South Pass, but owing to the uncommon low stage of the Mississippi, in connection with the fact that the dam was only completed at a very recent date (June 4th, 1879), it could not justly be expected that effects should be produced so rapidly.

However, the arguments for the efficiency of Upper Dam and Island Dyke extension, to procure a least channel depth of twenty-six feet, are very strong, and seem to indicate an early realization of that depth.

The distance from point *T*, the west end of "Upper Dam," to the mean low water line on the opposite shore of Southwest Pass, measured at right angles to the current, is three thousand one hundred feet. In this space we crowd the volume of both Passes, the South and Southwest, and thus may produce the elements of an equation, by which to ascertain approximately the mean depth, which will be obtained on the concentrated section. Thus:

Mean area of section, South Pass	22 000	square feet.
" " " Southwest Pass	65 000	" "
Total	87 000	square feet.

$$\text{Mean depth} = \frac{87\,000}{3\,100} = 28.06 \text{ feet.}$$

With a mean depth of twenty-eight feet, and the probability of greater depths close to the point, where the volume finds relief from the

Some of the names of dams and dykes at the head of the Passes which appear in Mr. Corthell's paper, were recently changed by Mr. Eads. The following list gives the corresponding names in both papers;

Dam II is now called Lighthouse Dam.

T Head Dam I is now called Island Dyke.

T Head Dam II is now called Lighthouse Dyke.

head of water collected immediately above the line of the works, we may safely look for the day, not far distant, when we may say that a channel of thirty feet in depth will be obtained between the Mississippi river and the Gulf.

NOTE.—Since the presentation of the above paper at the convention at Cleveland, the following official information has been secured, and is added to complete the record:

1. On June 18th, 1879, a channel of 26 feet in depth, and at no point less than 200 feet wide, was obtained through the jetties.

2. On July 8th, 1879, a channel of 30 feet in depth, without regard to width, was obtained through the jetties. (See Plate XLI, Bar Survey by United States Engineers.)

3. On July 10, 1879, a navigable channel of 26 feet in depth was obtained at the head of the Pass, connecting the deep water in the Mississippi with the deep water of the South Pass.

Thus, in less than four years from the day on which work was begun, the final result aimed at has been accomplished, and there exists now at the mouth of the Mississippi a channel which will constitute the greatest commercial highway in the world.

SECTION OF JETTIES.

BETWEEN EAST POINT AND 8000 RESP. 9000 FEET SEAWARD

finished according to Plans

SEE TEXT PAGE 191.

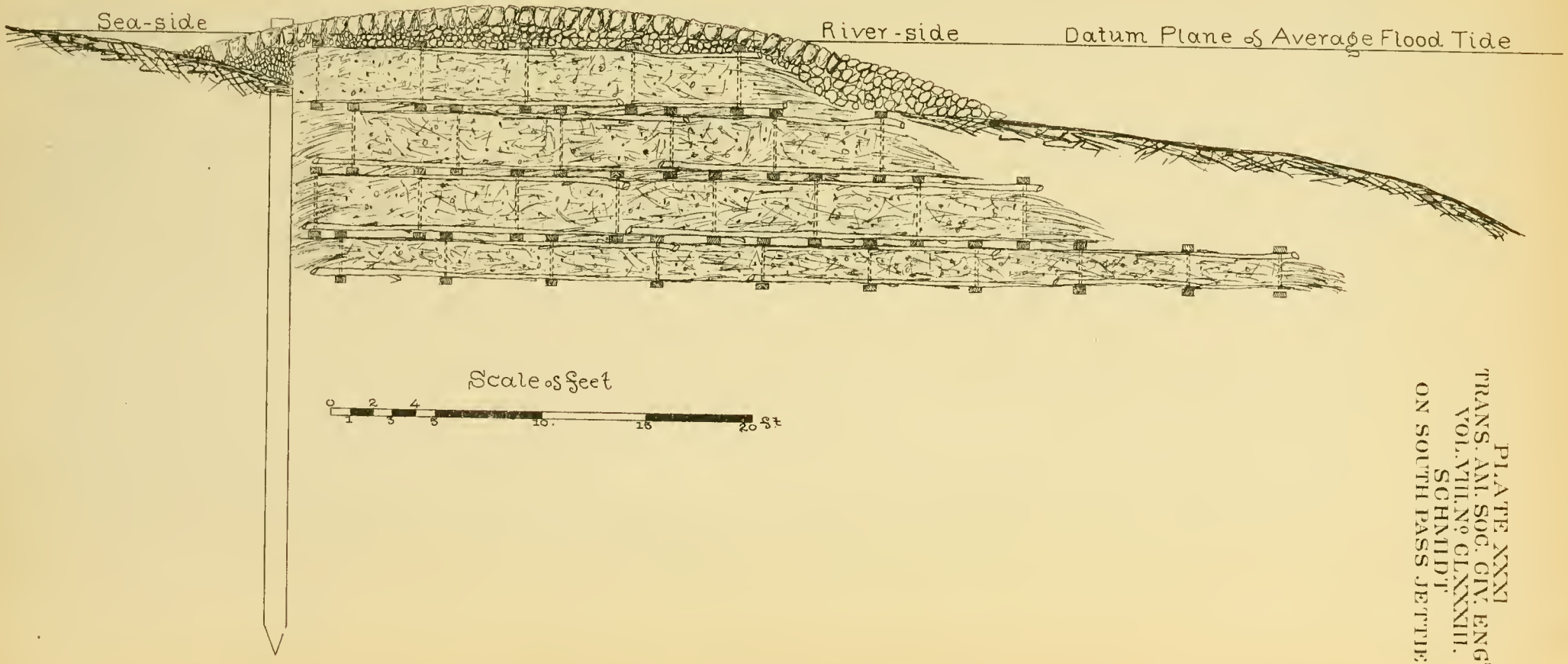

PLATE XXXI
TRANS. AM. SOC. CIV. ENG'R'S.
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ON SOUTH PASS JETTIES.

SECTIONS

of the lower parts of the jetties, finished according to plans.

SEE TEXT, PAGE 192. 204.

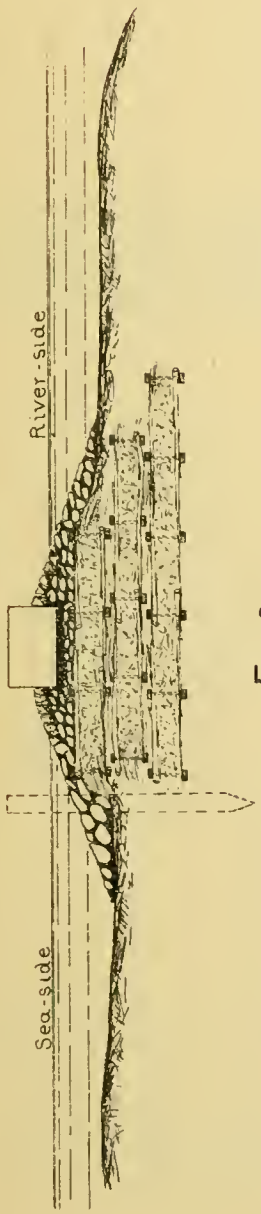

FIG. 1.

SECTION, 9000 FT SEAWARD FROM EASTPOINT.

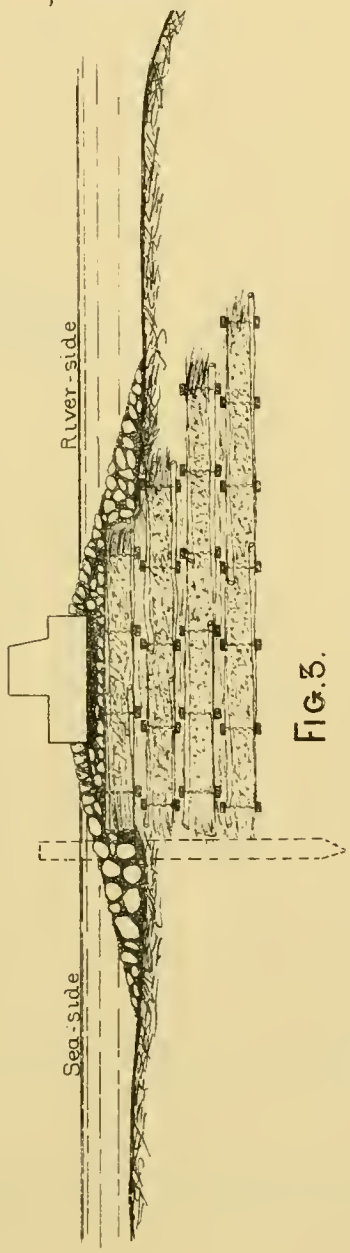

FIG. 2.

SECTION, 10400 FT SEAWARD FROM EASTPOINT.

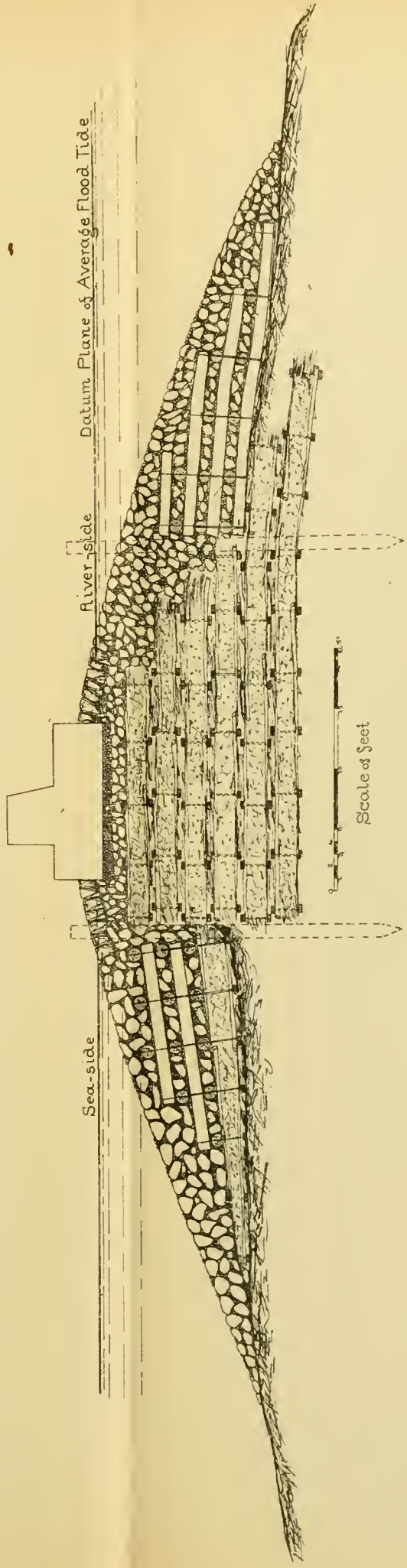

FIG. 3.

SECTION, 11800 FT SEAWARD FROM EASTPOINT.

PLATE XXXII
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ON SOUTH PASS JETTIES.

FIG. 1.

SECTION OF WEST JETTY AS ORIGINALLY PROPOSED
4200 FT SEAWARD FROM EAST POINT

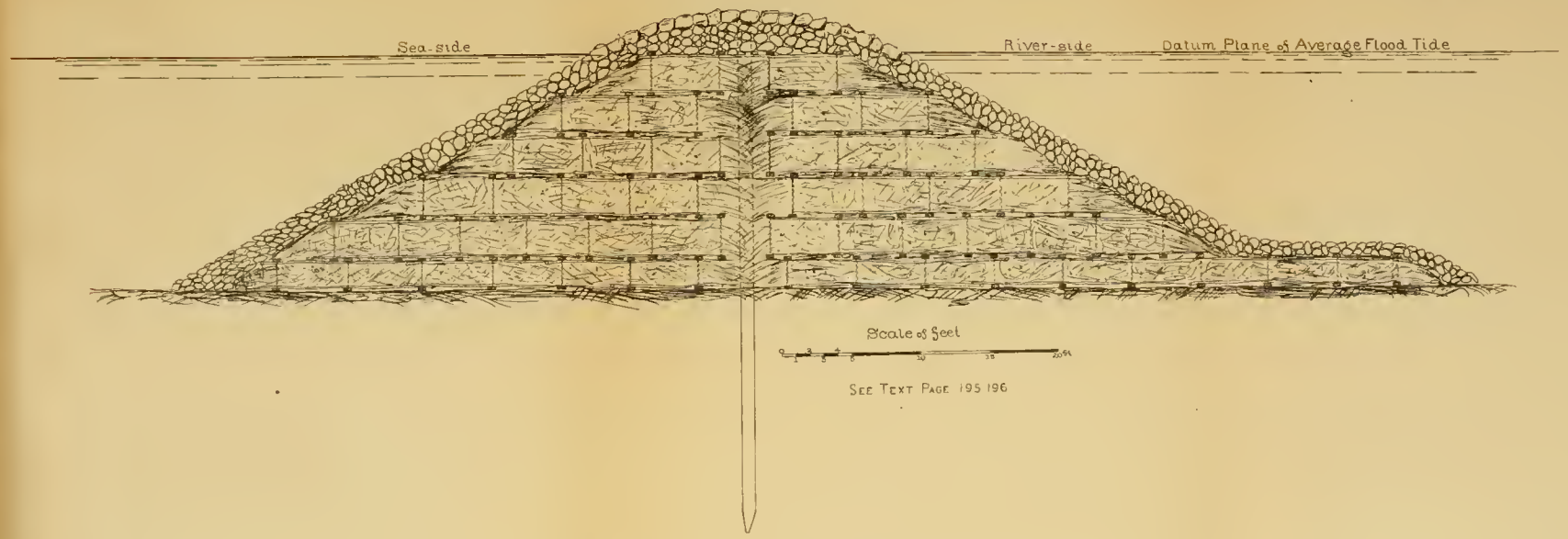


FIG. 2.

SECTION OF WEST JETTY AS CONSTRUCTED
4200 FT SEAWARD FROM EAST POINT
SHOWING PROTECTING DEPOSIT ON SEA- AND RIVERSIDE

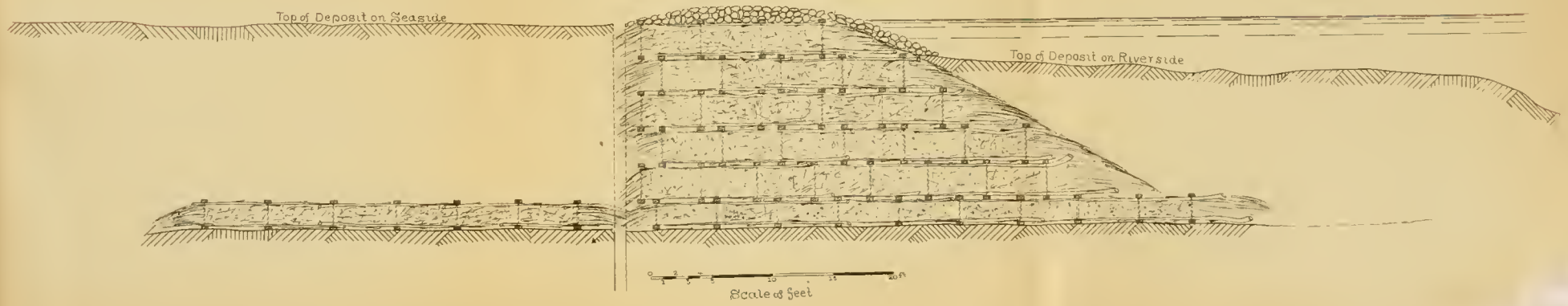


FIG. 1.

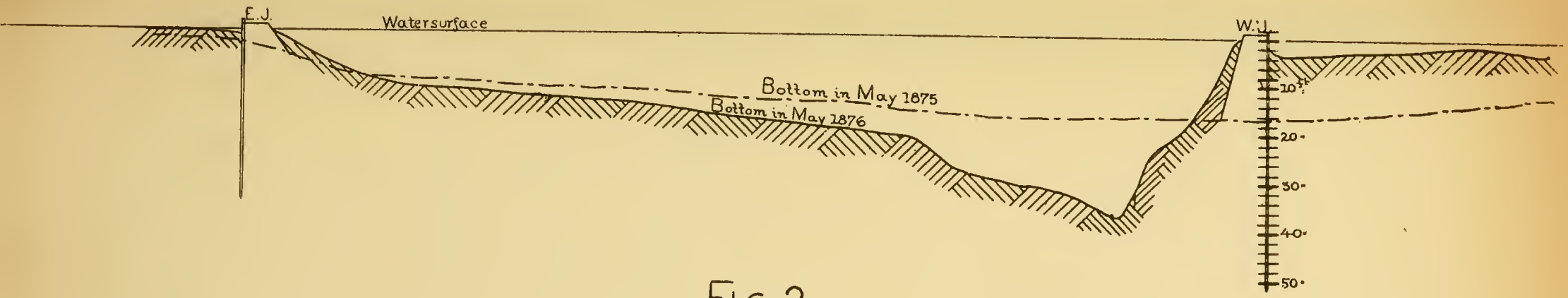
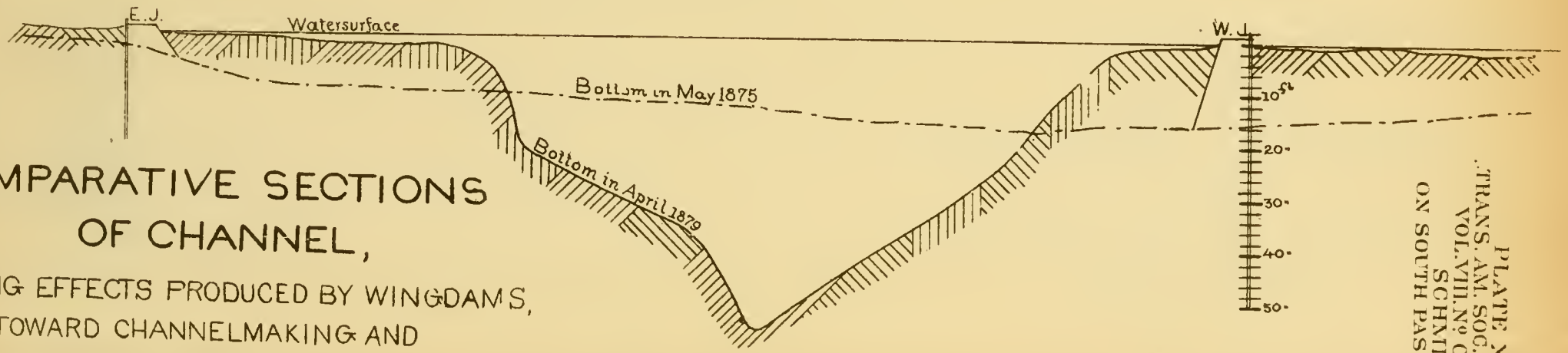


FIG. 2.



COMPARATIVE SECTIONS OF CHANNEL,

SHOWING EFFECTS PRODUCED BY WINGDAMS, TOWARD CHANNELMAKING AND PROTECTION OF JETTIES

SEE TEXT, PAGE 197.

Horizontal-Scale of feet.

PLATE XXXIV.
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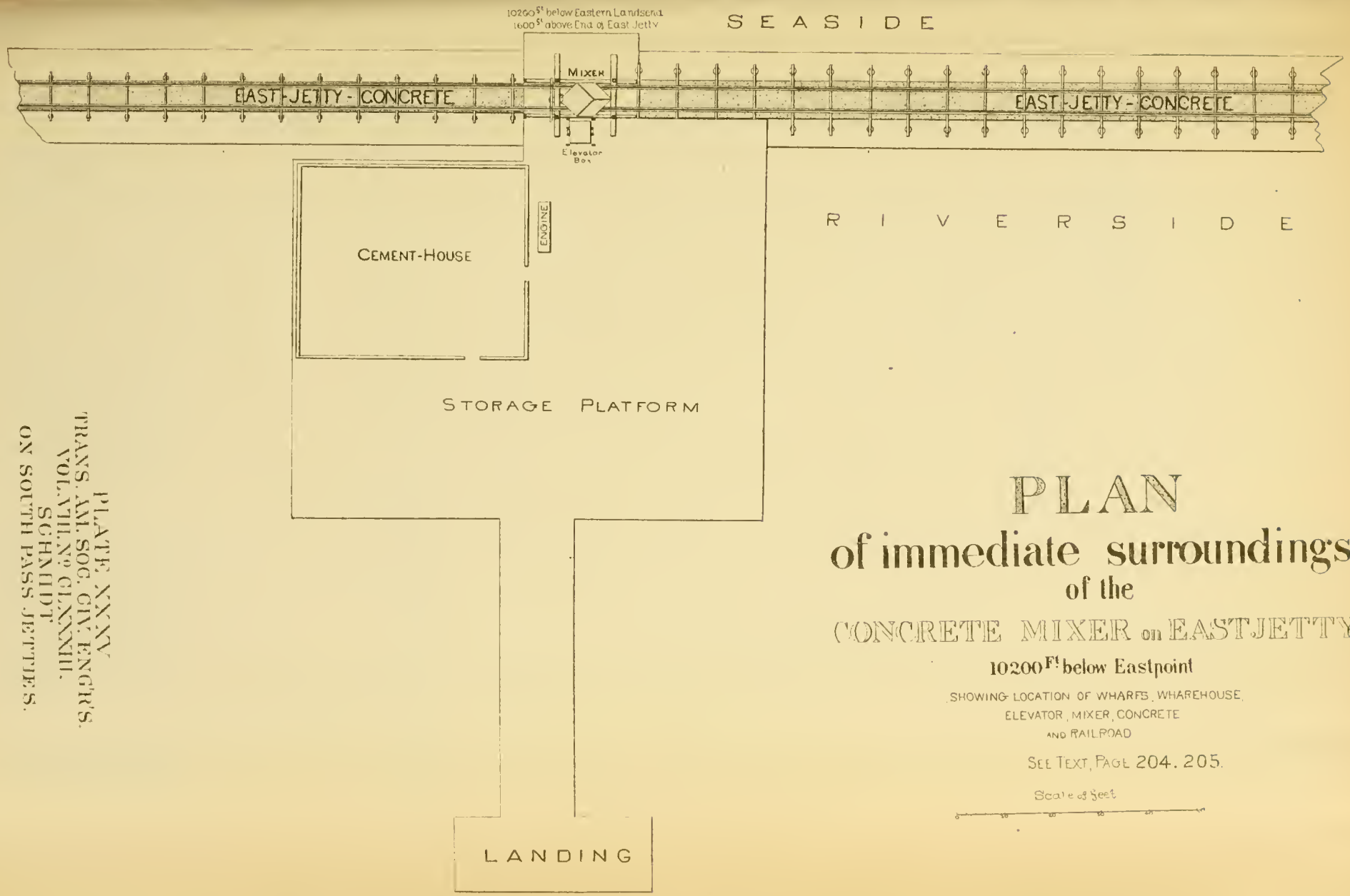
SCHMIDT
ON SOUTH PASS JETTIES.



PLAN
of immediate surroundings
of the
CONCRETE MIXER on EAST JETTY
10200 Ft below Eastpoint

SHOWING LOCATION OF WHARFS, WHAREHOUSE, ELEVATOR, MIXER, CONCRETE AND RAILROAD

SEE TEXT, PAGE 204. 205.

PLATE XXXV
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SCHMIDT
ON SOUTH PASS JETTIES.

PLATE XXXVI.
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SCHMIDT
ON SOUTH PASS JETTIES.

CONCRETE MIXER on EASTJETTY

10·200 Ft below Eastpoint

SEE TEXT PAGE 205, 207.

SIDE ELEVATION

LOOKING EAST

Scale of Feet

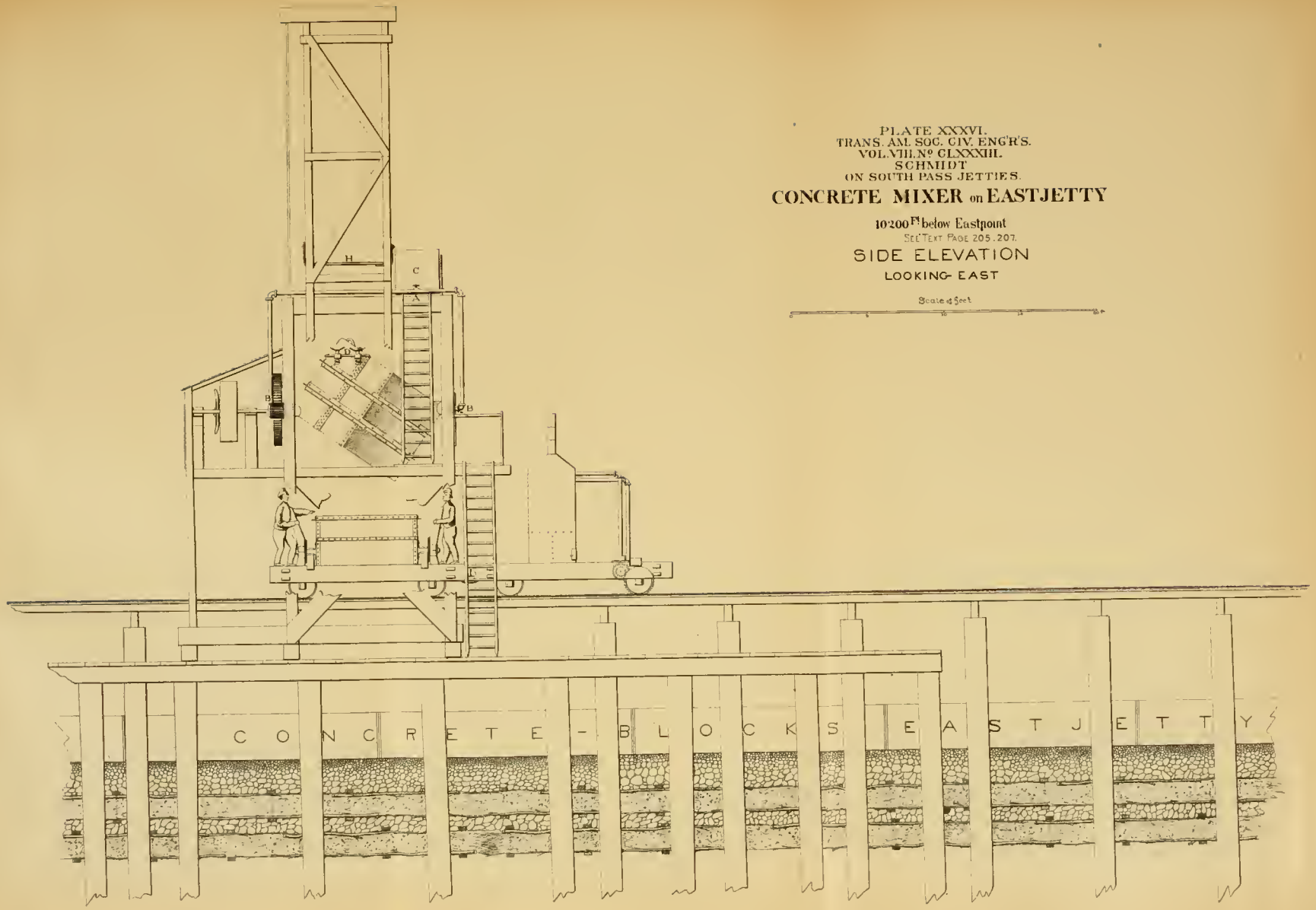

PLATE XXXVII
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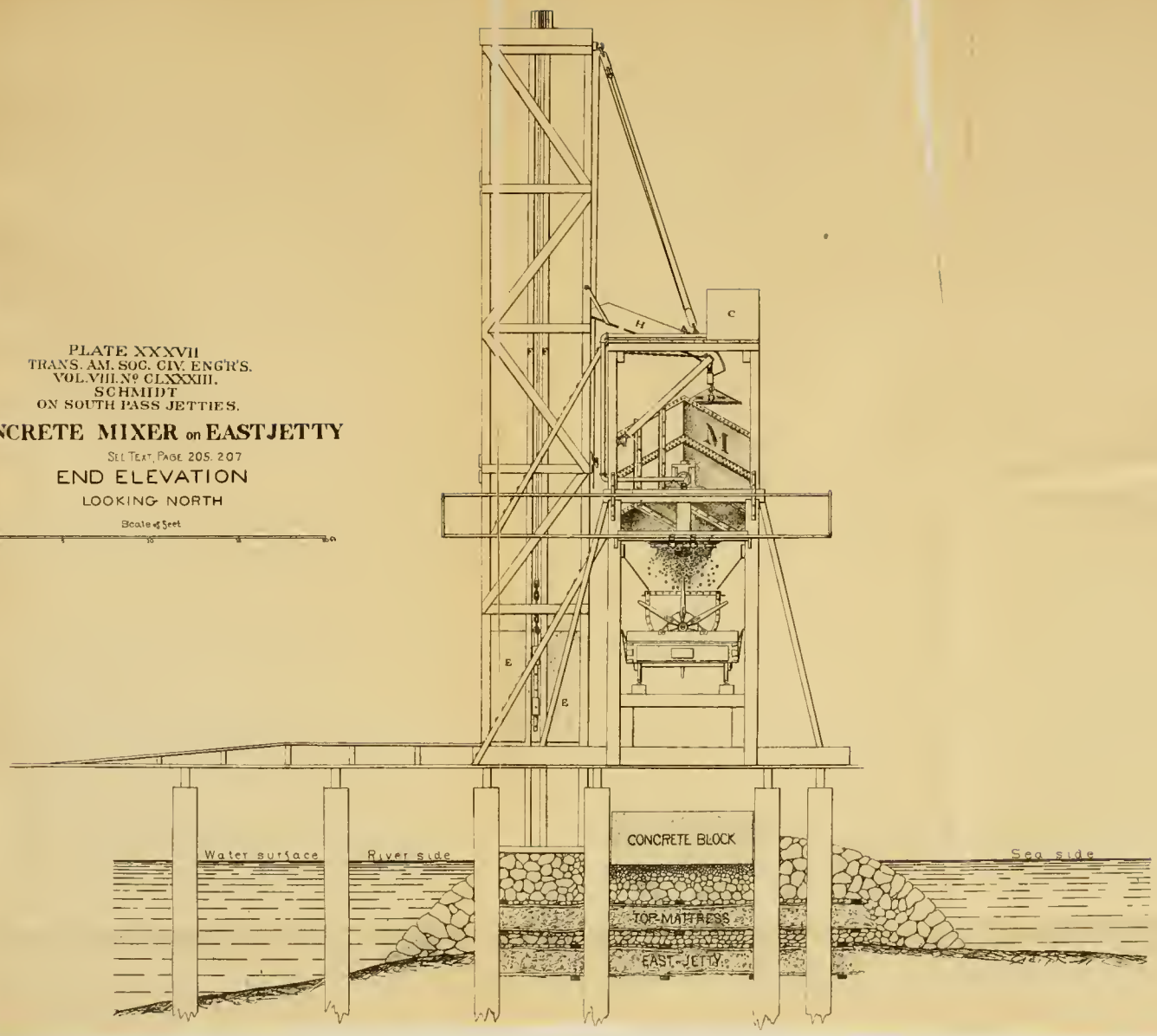
CONCRETE MIXER on EAST JETTY

SEE TEXT, PAGE 205, 207

END ELEVATION

LOOKING NORTH

Scale of Feet



SEE TEXT, PAGE 208, 211 216. FIG 1.

MOULD BOX FOR CONCRETE BLOCKS

TOP VIEW

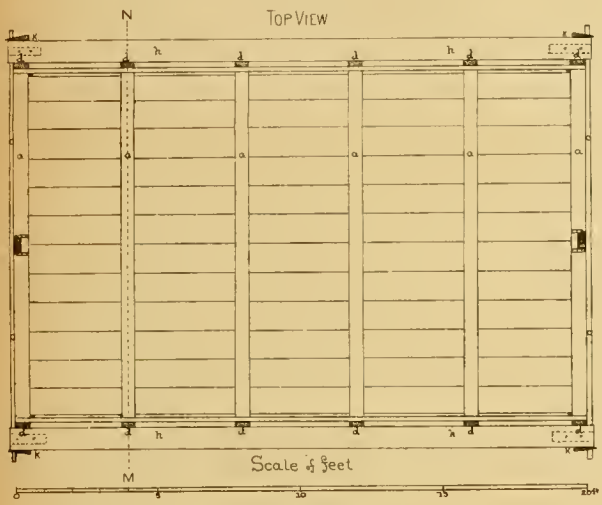


FIG. 2.

MOULD BOX FOR CONCRETE BLOCKS

END ELEVATION

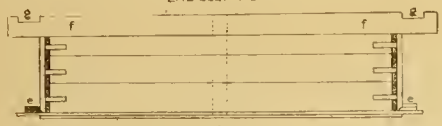


FIG. 3.

MOULD BOX FOR CONCRETE BLOCKS

SECTION ON M-N

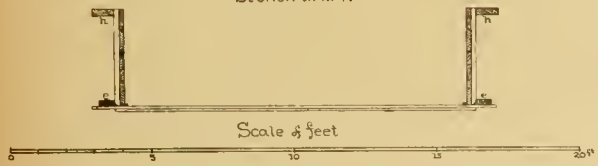


PLATE XXXVIII.
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FIG. 4.

PALMETTO-CRIB-WORK

TOP VIEW

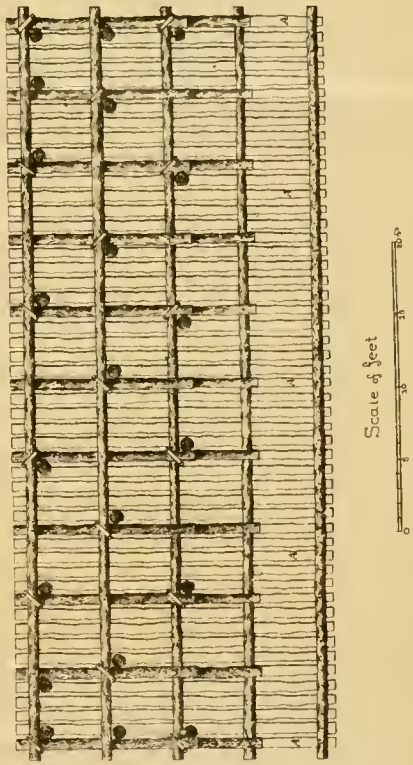
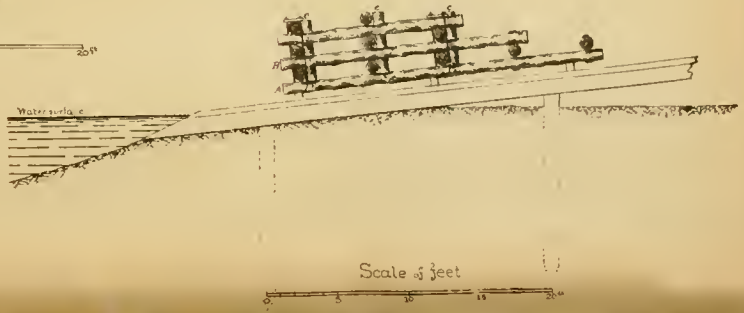


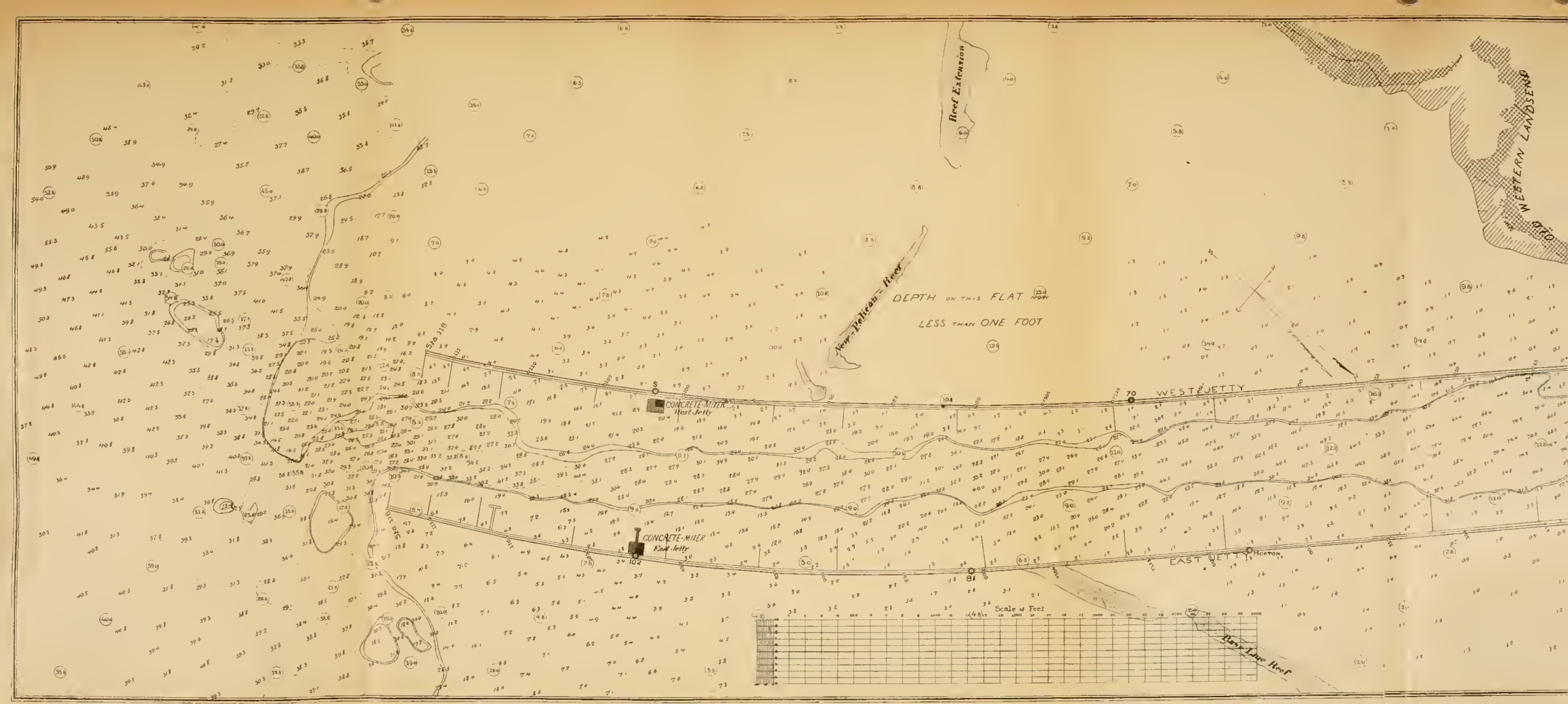
FIG. 5

PALMETTO-CRIB-WORK

END ELEVATION,

SHOWING POSITION ON WAYS




Reef Extension
WESTERN LANDSEND
New Pelican Reef
DEPTH ON THIS FLAT
LESS THAN ONE FOOT
CONCRETE-MIXER
West Jetty
CONCRETE-MIXER
East Jetty
WEST JETTY
EAST JETTY
Horton
Scale of Feet
Reef Line Reef

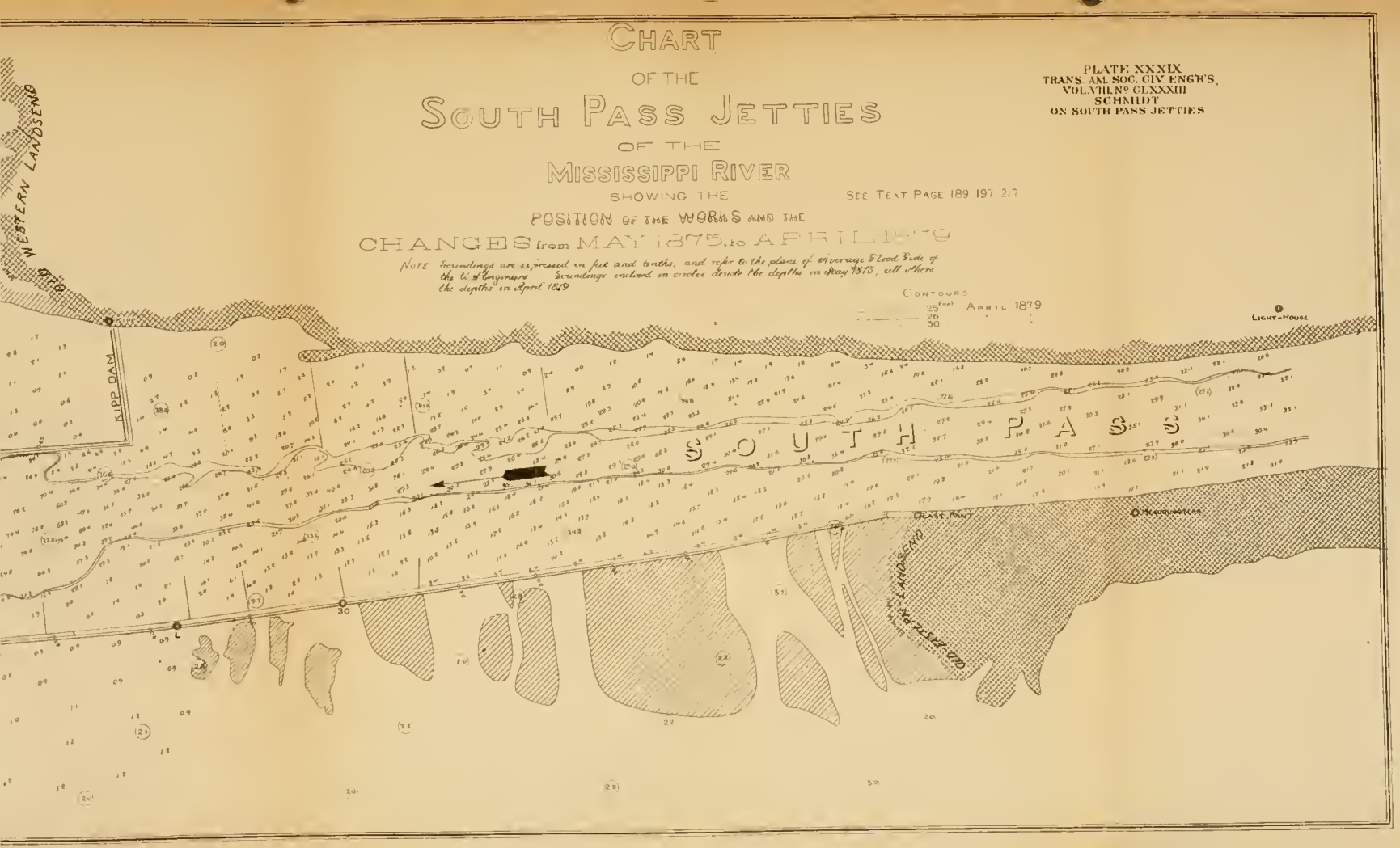


CHART
OF THE
SOUTH PASS JETTIES
OF THE
MISSISSIPPI RIVER
SHOWING THE
POSITION OF THE WORKS AND THE
CHANGES from MAY 1875, to APRIL 1879
PLATE XXXIX
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SEE TEXT PAGE 189 197 217
NOTE Soundings are expressed in feet and tenths, and refer to the plane of average Flood Tide of the U. S. Engineers. Soundings enclosed in circles denote the depths in May 1875, all others the depths in April 1879
CONTOURS
25 Feet
26
30
APRIL 1879
WESTERN LANDSEND
KIPP DAM
LIGHT-HOUSE
SOUTH PASS
EAST JETTY
OLD EASTERN LANDSEND

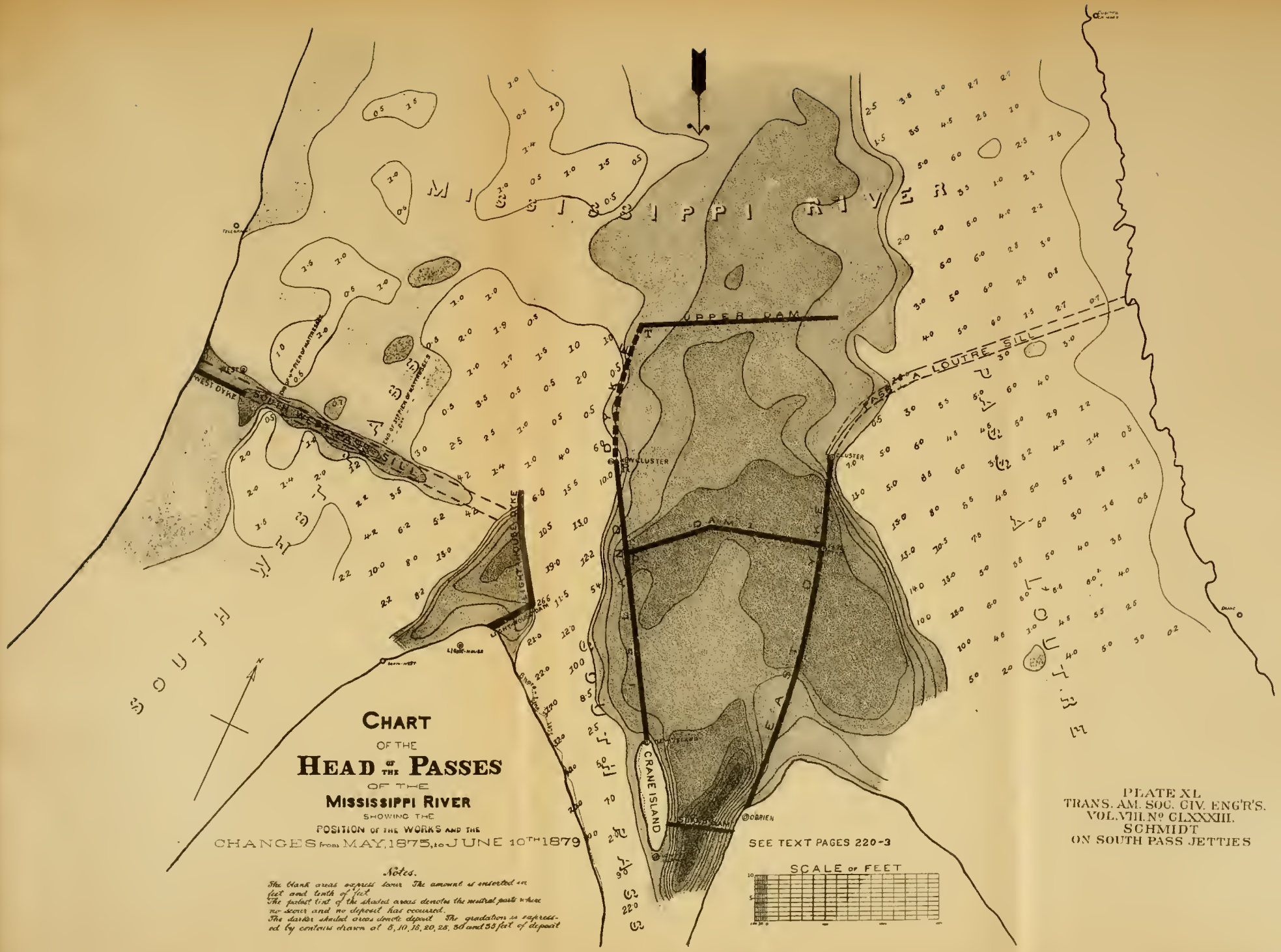

PLATE XL
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VOL. VIII. No. CLXXXIII.
SCHMIDT
ON SOUTH PASS JETTIES

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CLXXXIV.

(Vol. VIII.—September, 1879.)

THE OCEAN PIER AT CONEY ISLAND.

By CHARLES MACDONALD, C. E., Member of the Society.

PRESENTED AT THE ELEVENTH ANNUAL CONVENTION, JUNE 17TH, 1879.

Coney Island is a recent sand bar formation pertaining to the town of Gravesend, at the southwestern corner of Long Island (see Plate XLII), and forming the eastern boundary of the outer bay of New York.

Until within the last three or four years the exceptional advantages afforded by this island for surf bathing and direct access to the cooling atmosphere of the Atlantic were allowed to remain undeveloped and almost unknown, with the exception of a small strip at the west end occupied by Norton & Murray's Hotel, which was reached by boat from a landing in Gravesend Bay.

In the year 1877 the Manhattan Beach Hotel, at the east end of the island, was opened to the public as a place of summer resort, and the extraordinary success attending this enterprise, which included also a railroad to Bay Ridge, stimulated similar investments in succeeding

years, until at this present there is scarcely a foot of beach unoccupied, and the number of daily visitors is to be counted by tens of thousands.

Although the facilities for communicating with the island have kept pace with the rapidly increasing traffic, they all involve more or less railroad transit, which, when considered in connection with the heat and dust of midsummer, and the necessary steamer transfer for all except Brooklyn passengers, too often becomes a fruitful source of inconvenience and delay.

The iron pier which forms the subject of the following paper was built with a view of relieving this difficulty, by affording means of landing directly upon the beach from steamers connecting with all points in the harbor, and at the same time presenting attractions as a promenade and bathing pavilion.

Its construction, involving as it does the application of the water jet as a means of sinking piles, is believed to possess some features of professional interest.

The water jet as a method of sinking piles through sand has been extensively used both in this country and abroad for so many years, and its efficiency and economy are so fully recognized, as to render a general description of the system quite unnecessary.

L. Y. Schermerhorn, Assistant Civil Engineer U. S. A., Member of the Society, has prepared a table "showing application of the water jet to the driving of piles," from which it would appear that as early as the year 1852 piles were sunk by water jet in the foundations for a wharf and warehouse at Decrow's Point, Matagorda Bay, Texas.

In 1854 hollow cast iron pipes were sunk "by jet passing through and discharging at bottom," in the construction of the Pungateague Bay Lighthouse, Chesapeake Bay, the work being in charge of C. Pontez, Assistant Engineer, under Major H. Bache, U. S. A.

In the construction of the Levan and Kent viaducts, England, in 1856, James Brunlees, used "hollow cast iron piles with jet forced through pile and delivered below point, also wooden piles by water jet passing along side of pile."

In 1862, 5 000 wooden piles were sunk in connection with naval operations in Mobile Bay by means of a "jet through detached tube discharging below point of pile."

At Kansas City, 1867 to 1869, O. Chanute, Member of the Society, sank wooden piles by jet, as also the caisson, Pier No. 4, for the bridge crossing the Missouri river at that point.

MAP

OF

NEW YORK HARBOR

Scale of Miles.

PLATE XLII
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floor, with kitchen, laundry, and offices below. The promenade deck is covered by a light roof spanning the entire width of 50 feet. At the mid-section, refreshment rooms occupy the enlargement, so as to leave the promenade unobstructed, while over head provision is made for aerial sleeping apartments, surmounted by a clock tower reaching a height of 80 feet above the water. The entire pier head is enclosed as a music hall. with refreshment rooms at the corners and elevated observation galleries on the ocean face.

It is questionable whether buildings presenting any considerable surface to the action of the wind, in such an exposed position and upon such a foundation, may be considered as entirely safe. The present structures have thus far shown no evidence of weakness under the ordinary summer storms; it remains to be seen how they will weather the more violent tempests of other seasons of the year. If the experiment proves successful it will, doubtless, lead to many novel additions to the architecture of that attractive little island.

The wrought iron piles used in this structure are lap-welded tubes, 8⅝ inches outside diameter, and half an inch thick, except at the shore end where they are of the standard thickness ⅜ of an inch. As delivered from the works of Messrs. Morris, Tasker & Co., these tubes were furnished with a standard thread at each end and a coupling 5 inches long, by which they were combined at the site, forming the required length. They were also treated, while hot, with a preparation of coal tar and oil inside and out, with a view of preserving the iron from oxidation. This, however, has not proved to be satisfactory, as in many instances the coating has already been washed off. In all such cases it would be desirable to use a marine varnish of some brand which has been thoroughly tested.

All piles from the point where the two floors begin, have their upper sections 12 feet long, so as to bring the coupling directly under the casting supporting the lower floor; the remaining sections do not exceed 20 feet.

In the direction of the length of the pier, the distance between each row is 20 feet.

At the shore end there are eight piles in a row; the four center ones being 16 feet 8 inches, and the outer piles, on either side, 17 feet 6 inches from center to center.

Throughout the main stem there are four piles in a row, 16 feet 8 inches apart.

PLATE XLIII
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FIG. 1

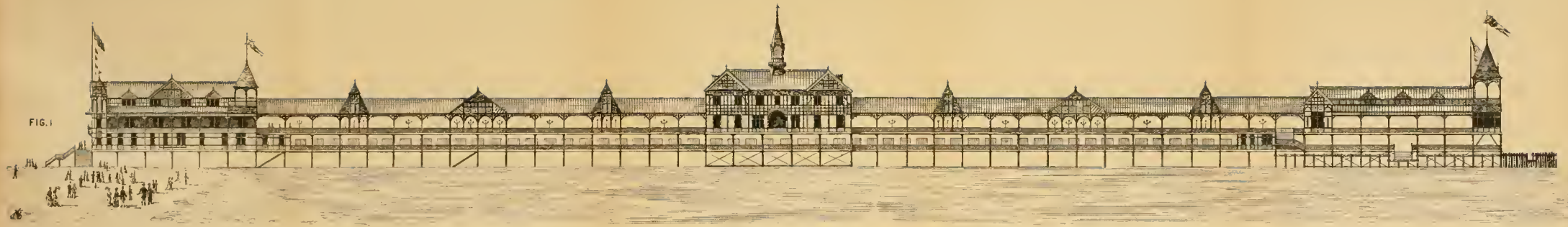
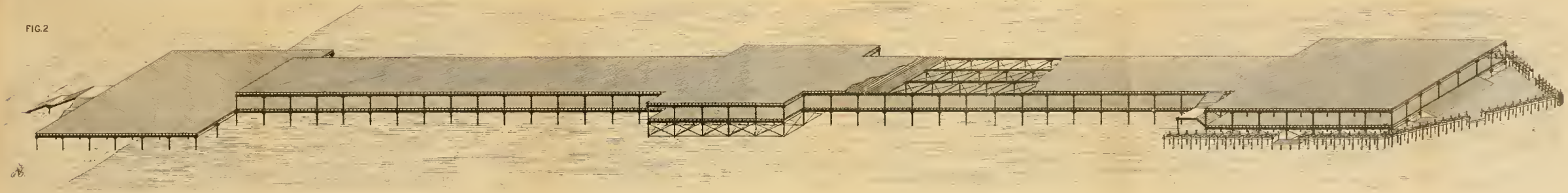


FIG. 2



The mid section has six piles in a row, 16 feet 8 inches apart, while at the pier-head there are eight piles in a row; the two on either side the main stem being 12 feet 6 inches between centres. (See Fig. 2, Plate XLIII.)

The disks, which form a supporting base for the piles, are of cast iron, 2 feet in diameter and 9 inches deep. On the upper side is a socket in which the pile rests, and is secured by four set screws; underneath there is a conical projection, strengthened by ribs, through which an opening 2 inches in diameter is left for the water jet.

On the tops of the piles are cast-iron capitals, secured to them by four set screws and fitted to receive the wrought-iron beams which form the support of the floor; they are also furnished with cylindrical lugs for connecting a system of diagonal brace-rods 1½ inches in diameter.

The beams in the lower floor are supported upon castings clamped around the piles directly above a coupling. These castings have similar lugs for brace-rod connections.

The floor beams are laid lengthways of the pier, and are secured to the castings by ⅞ inch bolts through the lower flanges.

Throughout the upper floor, and in both floors at the pier-head, these beams are 15 inches deep and 150 pounds per yard. Under the bathing houses they are 10 inches deep and 105 pounds to the yard; and at the shore end 12 inches deep and 125 pounds per yard.

They are connected transversely at each row of piles by 6-inch beams, with angle-iron lugs, which are bolted directly through the webs of the main beams; where there are two floors the lower struts are 3 by 5 inches T iron, bolted to the clamp castings. Suitable provision is made for changes in length due to the temperature, by slotting the bolt holes.

As an additional precaution against the possible effect of wind upon the buildings at the mid section and pier-head, a system of vertical bracing in both directions was subsequently introduced between the lower floor and high tide. This consists of 1½-inch rods, connected to the piles by cast-iron rings—which are held in place by tap-bolts—and horizontal struts attached to the same rings at the level of high water. These struts are made up of two 6-inch channel-bars, latticed in the form of an] [section, similar to the lateral struts used in bridges; they necessarily present a considerable surface resistance to the force of the breakers and may prove to be of doubtful utility. Their action in severe weather will be watched with interest.

The timber flooring consists of 3 by 12 inches Georgia pine joist, spaced two feet apart, upon which 3 by 6 inches planking is laid for the upper floor, and 2 by 6 inches for the lower, the whole being suitably spiked and calked.

Owing to the very limited time allowed for the completion of the structure, it was impossible to make suitable soundings and borings in order to determine the proper length of piles ; but, from the imperfect data at hand, it was decided to sink the first row 10 feet in the sand and gradually increase the depth to 15 feet at the outer end, where it was expected that the water would be 14 feet at high water. Very soon after work was commenced, it was found that this arrangement could not be adhered to, owing to the irregular slope of the bottom ; accordingly about 1 000 additional feet of tubing were ordered, and the piles were made up to lengths which were frequently regulated by the sections of tubing on hand rather than by a strict adherence to the original plan.

At the pier head the water was actually found to be 16 feet deep, and the piles driven in this section were generally 57 feet long, giving a depth of 17 feet in the sand.

In the operation of sinking the piles the water jet was applied through a pipe 1½ inches in diameter, extending down through the pile and disk, and about 2 inches beyond. This pipe was held firmly in position by wooden blocks driven in at the pile head, and connected with the pump by a rubber hose. The water pressure was thus transmitted directly to the sand at the foot of the pile, with the effect, as is well known, of transforming it into a semi-liquid mass, through which the pile settles easily to the required depth.

All piles in the shore section were driven by a machine very similar to the ordinary land pile driver, which could be rolled on the sand as the tide permitted ; the pile was kept vertical in its descent by a recess in the machine at its base, while the upper end was clamped to a guide block moving freely in the leaders.

After the completion of the shore end a scaffold was built at a level with the upper deck, upon which was erected the travelling derrick. represented in parallel perspective, Plate XLIV, in which it will be observed that there are four pairs of leaders, sustained upon a framework projecting beyond the points of support, and at right angles to the axis of the pier. These leaders are spaced 16 feet 8 inches apart to correspond with the piles in each row, and the length of the overhang is equivalent to the distance between the rows.

PLATE XLIV
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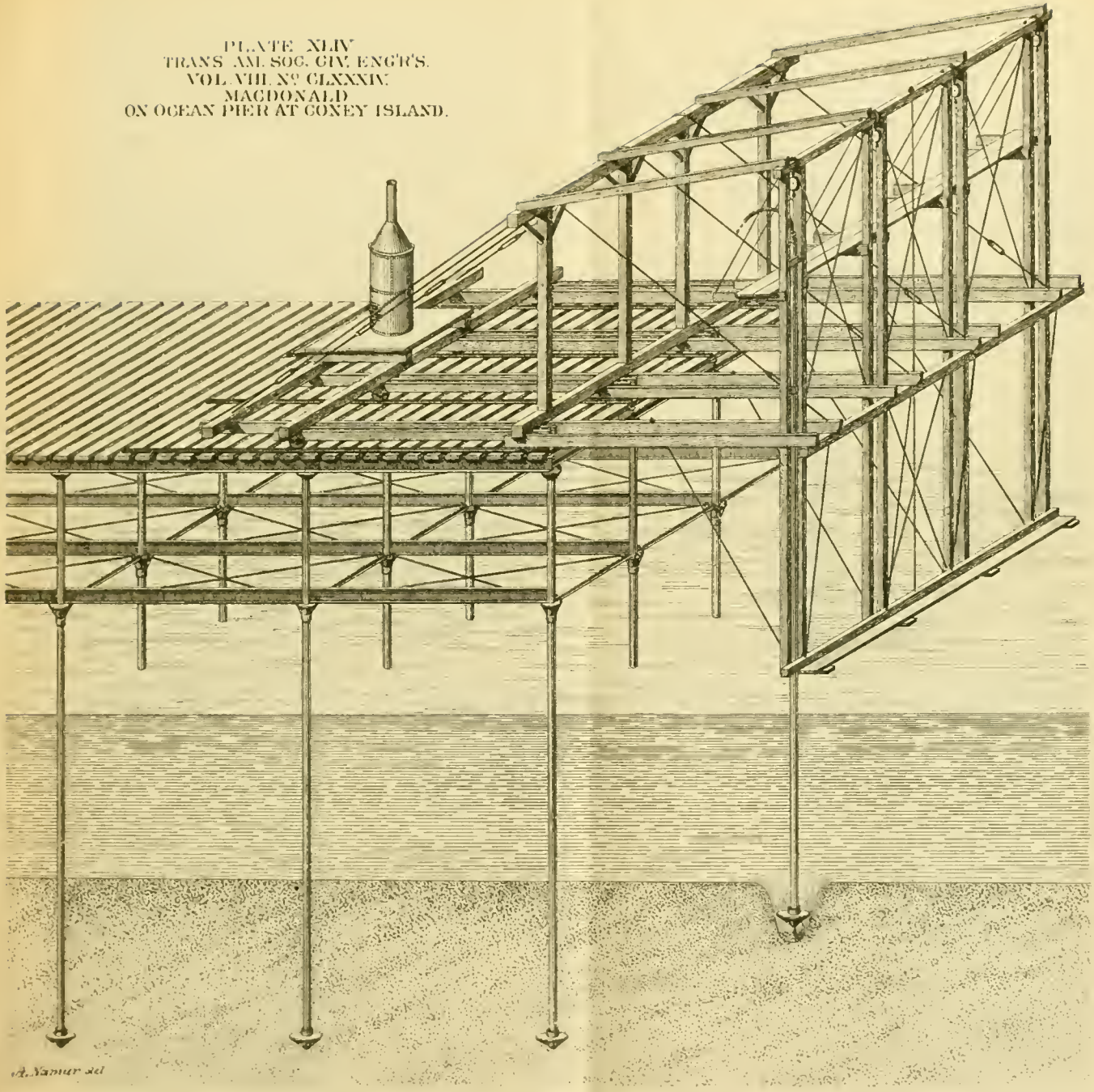
ON OCEAN PIER AT CONEY ISLAND.



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The projecting portion is sustained by four diagonal truss rods passing over upright posts directly over the outer row of wheels, and secured at the rear of the platform.

The entire weight is carried upon two rows of grooved wheels, four in each row, and so arranged as to lead in the line of piles.

At the foot of the overhang, which is 6 feet above high water, recesses are left between the leaders for the guidance of the pile in its descent, the upper end being fastened to a block moving between the leaders.

All the piles in the main stem were driven by the aid of this machine; and it is sufficient to say that its efficacy was fully demonstrated by the accuracy and economy of the work done, and the remarkable rapidity with which it was accomplished.

The outer piles at the end section were driven by the aid of booms rigged on the sides of the main derrick, and projecting guides attached to those already driven.

After the last of the four piles had been placed, at the ocean end, this derrick was dismantled, and the leaders placed upon a frame extending 25 feet on either side, in the proper position for driving the extra rows to complete the pier head, as the machine rolled backward.

Plate XLV, which is reproduced from a photograph taken from the ocean end, represents this modification. On the left a pile is being swung into position for sinking; the small tube extending beyond the end is the 1½ inch pipe used for transmitting the water jet, as before described. In the foreground the connection of the beams and bracing with the piles is shown, and on the right a beam is being placed in position upon piles already sunk. Three of the cast-iron disks are to be seen on the centre platform, one of them already fastened to the end of a pile ready for sinking. Directly over the middle of the frame is a lamp, used for the electric light, to be referred to hereafter.

Plate XLVI represents a photograph taken from the rear of the derrick after the pile shown in Plate XLV had been sunk to the proper depth; this is indicated by a spirit level and straight-edge shown in position, as also the line of hose and its connection with the pile. As long as the jet was kept in motion the pile was easily raised or lowered to the required level, after which the fall lines connected with the pile were made fast at the hoisting engine and the pump stopped, when a very few minutes sufficed to settle the sand back into its place, and the pile became a fixture upon which the iron work could be placed without producing an appreciable settlement.

When no serious obstructions were met with, the time expended in driving a row of piles with the original derrick, placing the iron beams and temporary track and rolling out for the next row, was six hours during the day time, and eight hours on the night shift.

For the first 200 or 300 feet from the shore the piles went down quite rapidly and at a uniform rate, but as the work progressed, and a greater depth became necessary it frequently happened that the pile would bring up on some tenacious material which was assumed to be clay, and through which the water jet, unaided, could not be made to force a passage. In such cases it was found that by raising the pile about six inches and allowing it to drop suddenly, with the jet still in operation, and repeating as rapidly as possible, the obstruction was finally overcome; although in some instances five or six hours were consumed in sinking as many feet. It was not possible to determine the character of these deposits from actual samples recovered, but from the action of the pile in passing through, they were assumed to be clay pockets. These deposits did not appear to extend in layers over any distance, as the experience with one pile would be no criterion for the next; and they varied in thickness from six inches to three feet.

The pumping plant consisted of a Worthington pump with a 12-inch steam cylinder 8½-inch stroke, and a water cylinder 7½ inches in diameter. Also a No. 6 Cameron pump with a steam cylinder 10 inches in diameter, 9-inch stroke, and a water cylinder 6 inches in diameter. The suction hose was 4 inches in diameter, and the discharge hose, which was of four-ply gum, was 3 inches. The boiler was upright, 42 inches in diameter, 8 feet high, and containing 62 tubes 2 inches in diameter.

At first the pump and boiler were placed at the extreme shore end, on a platform 5 feet above high water; from which position all the piles to the end of the mid section were driven. The plant was then moved out upon the lower deck about 400 feet, bringing the pump 14 feet above high water. This arrangement did not give satisfactory results, as the force of the jet seemed to be very much reduced, and the piles occupied more time in sinking; accordingly the pumps were lowered upon a platform suspended four feet above high water, and no further trouble was experienced.

The Worthington pump, although a very old one, did good service. The Cameron also proved very satisfactory, with the one exception of the gum rings, which are inserted in the composition valves under

PLATE XIV.
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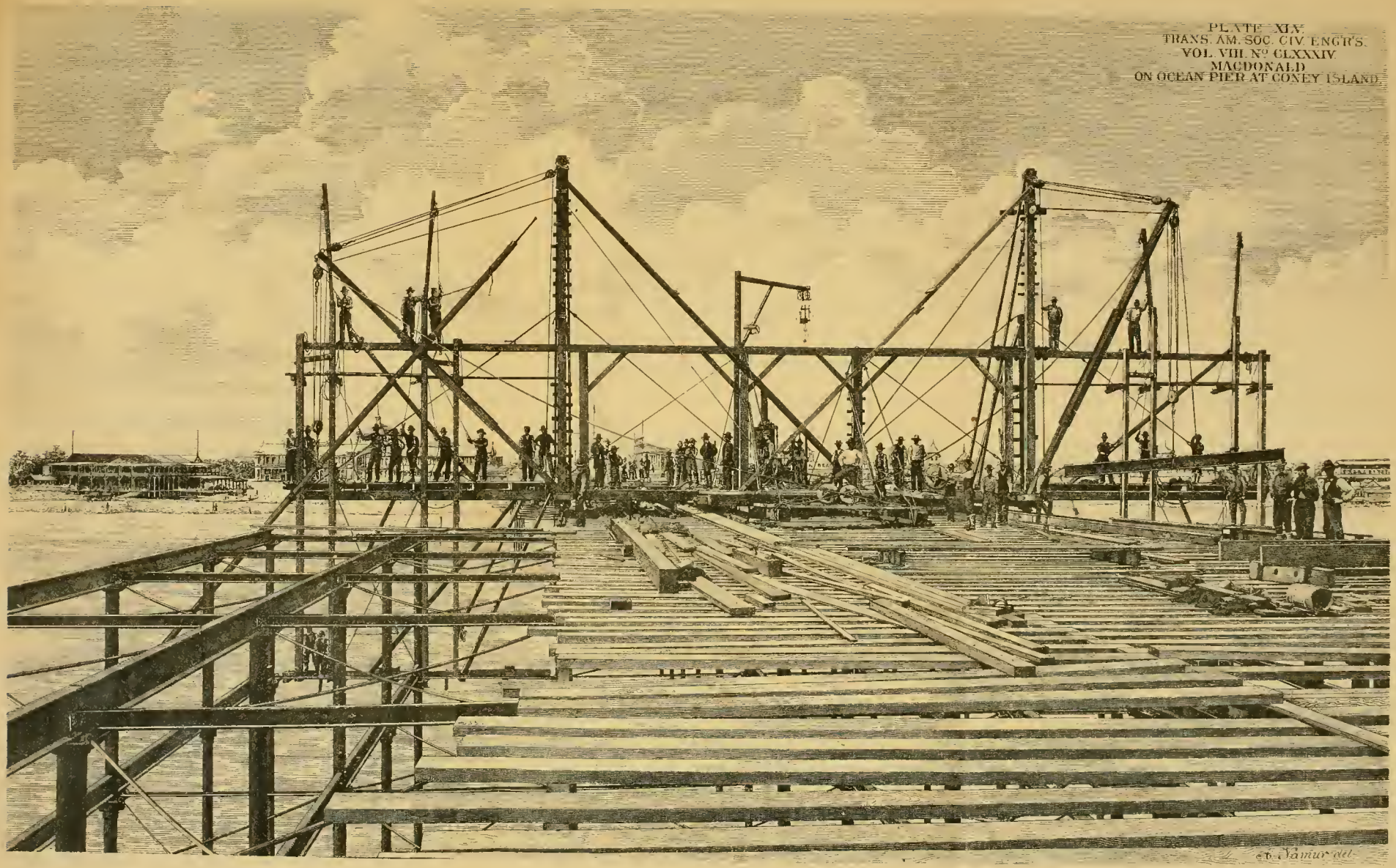

pressure. These rings wear out in some cases quite rapidly, and cannot be repaired on the work. Where such pumps are to be used at any distance from the factory, a number of extra valves should be provided. An abundance of steam was supplied by the boiler after the exhaust had been turned into the smoke stack and soft coal used as fuel, of which an average of about 160 pounds were consumed in sinking each pile.

With the power above described, it was found that piles could be driven in clear sand at the rate of 3 feet per minute to a depth of 12 feet; after that the rate of progress gradually diminished until at 18 feet a limit was reached beyond which it was not practicable to go without considerable loss of time. It is probable that with a larger pump, and possibly an improved method of applying the jet, better results can be obtained.

A few disks, 2½ feet in diameter, were tried, but much more time was required in sinking them. One 3-feet disk caused a delay of six hours in sinking 15 feet through very uniform sand.

It is to be regreted that the time allotted for the completion of this work, in order to make it available for the summer business, prevented the possibility of testing the merits of other methods of applying the water jet, and of determining the proper size of nozzle in proportion to the power used. In one of the last piles driven the experiment was made of forcing water through the pile itself instead of through an inner tube of small diameter; this was accomplished by clamping a cast-iron cap, with a 3-inch union attached to the top of the pile and connecting the hose directly with it. The joint at the junction of the disk and pile was also made water-tight, so that the water from the pump was forced through the 2-inch opening in the centre.

In this case the pile sank much more rapidly than before, and, although the pump was being driven at full speed, the hose frequently collapsed, which would seem to indicate that the resistance to the movement of the water had been materially reduced.

Upon one or two occasions it became necessary to raise piles which, by mistake, had been driven to a greater depth than required, and allowed to become firmly settled. This was accomplished by passing a jet down around the outside of the pile till the disk was reached, when the pile was easily raised by the blocks attached to the hoisting engine, and finally secured at the proper level.

The limit of safe loading for piles of this character has been assumed to be five tons per square foot of disk ; but of course this must be considered as dependent upon the depth of the pile in the sand, and possibly also the depth of water and compactness of the sand. Owing to the unequal distribution of the weight of the buildings, many of these piles sustain a load due to the structure alone, of 40 000 pounds, or $6\frac{3}{10}$ tons per square foot of disk ; to this must be added the weight of moving masses of people, and exceptional local loads, which have in some cases increased the pressure upon the disk to eight tons per square foot without causing any settlement which may be detected by the eye. This extreme practice is not recommended, however, where absolute rigidity of foundation is required.

The wooden piles around the pier head were also driven by a water jet ; the $1\frac{1}{2}$-inch tube used for the iron piles, being lashed to the side of the wooden pile at the top, and held in place at the bottom by three cleats nailed on the sides, forming an opening 2 inches square, through which the tube was easily drawn after the pile was sunk.

It was not found necessary to curve the tube so as to bring the jets under the centre of the piles. They did not exhibit any tendency to work over to the side on which the tube was secured, and were easily controlled in the descent by handspikes from a temporary staging.

As these piles were of pin oak, and consequently much heavier than water, they were settled to a depth of 12 feet without the additional aid of a hammer; but much time would be saved by the use of a regular pile driver *in connection with the water jet* where lighter piles were used or greater depths required.

The most difficult feature of the work was the short time allowed for its completion, in many cases compelling the resort to expedients which might have been improved upon had there been opportunity.

The contract was signed on the 5th of April last, requiring the completion of the pier, exclusive of buildings, by the 5th of June. On the 22d of April the first pile was sunk, and work was continued, with some interruption from high tides, until May 1st, when the shore section was completed. Four days were then expended in erecting the traveling derrick, Plate XLIV.

On May 6th, pile driving was resumed, and on the 28th the last row on the ocean end was finished.

May 29th and 30th were taken up in altering the derrick (Plate XLV.,

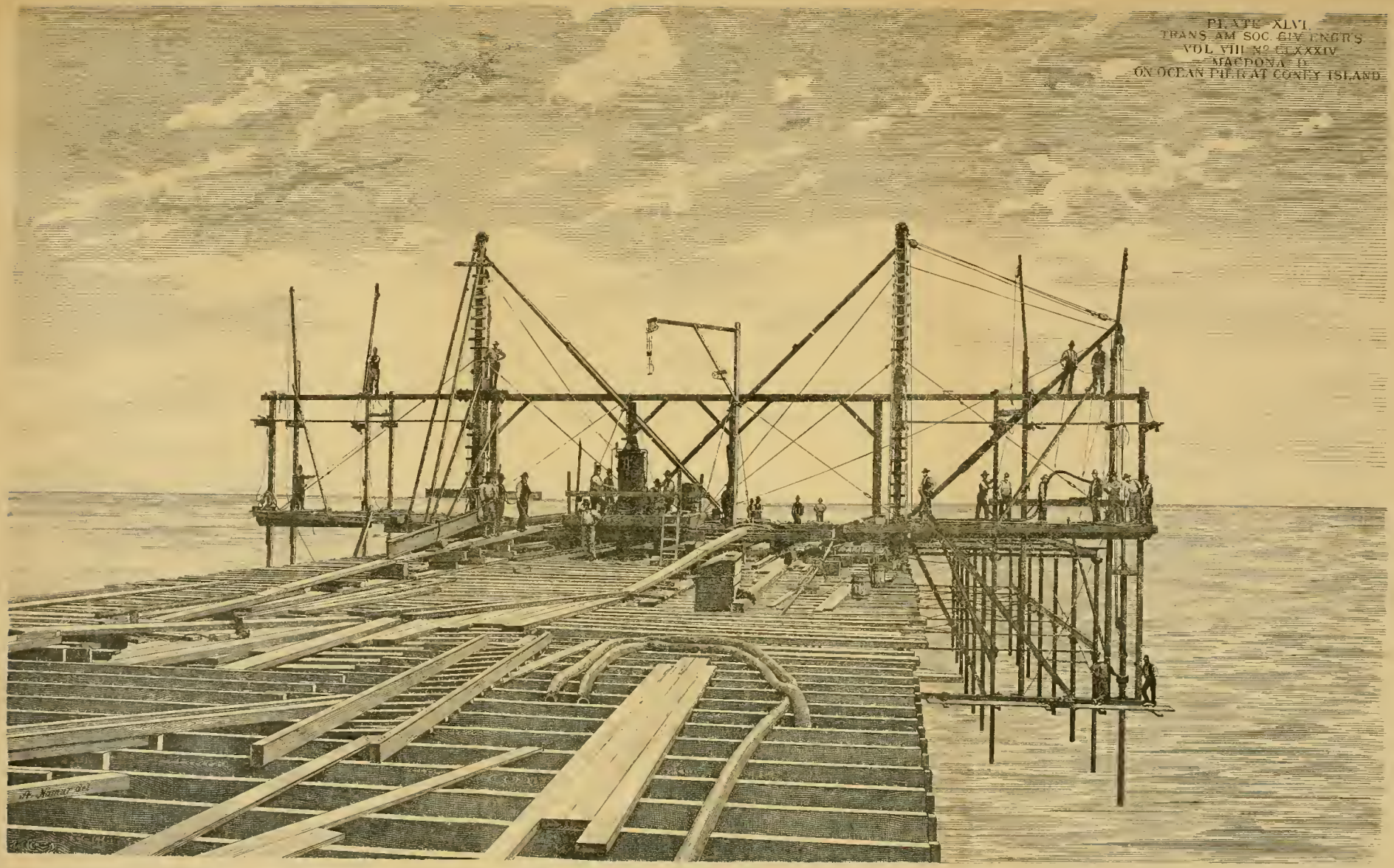
PLATE XLVI.
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ON OCEAN PIER AT CONEY ISLAND.

and on the 4th of June the pierhead was completed, making 286 piles placed, with all the iron beams and connections, in 38 working days. From the 15th to the 28th of May, work was prosecuted day and night, light being supplied by two electric lamps from the Dynamo-Electric Light Company, of Newark, N. J. So far as the light itself was concerned the results were very satisfactory ; with one lamp attached to the derrick and one at the shore end, no difficulty was experienced in working a full force of men. The power required to drive the machines, however, proved to be much greater than was represented. A 5-horse power hoisting engine, which was assumed to be sufficient for two lights was, in reality, only capable of driving one machine without being over taxed; and it became abundantly evident that the question of cost of fuel was a very important element in connection with electric illumination.

The pier was opened for business July 1st, and within the next sixty days upwards of 250 000 passengers had been registered, the largest number in any one day being 22 600.

The steamers *Columbia* and *Grand Republic*, rated at 1 800 and 1 900 tons respectively, make regular landings, thus far without injury to the staging. It is proper to state, however, that this portion of the structure is necessarily of a temporary character, and liable to require frequent repairs.

With the exception of the buildings the work was designed and executed by the Delaware Bridge Company, under the supervision of Messrs. Maclay and Davies, Engineers for the Ocean Navigation and Pier Company of New York.

The buildings were constructed upon the design, and under the direction of Messrs. Gamrbill and Ficken, architects, N.Y., to whose skill and originality of conception is largely due the fact that the iron pier at Coney Island is to-day one of the most attractive places on the coast.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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CLXXXV.

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STABILITY OF STONE STRUCTURES.

By WILLIAM H. SEARLES, C. E., Member of the Society.

PRESENTED AT THE ELEVENTH ANNUAL CONVENTION, JUNE 17th, 1879.

Structures in stone, wherever built or of whatever design hitherto, depend upon their weight for their stability. Whether they be the rough monoliths of the Druids at Stonehenge, or the monumental obelisks of Egypt, or the more elaborate and graceful columns of Greece, in every case the force of gravity has ever been the only force which gives stability. These pillar-like structures, however, have not been designed to resist any external forces which could overthrow them, except the force of the wind. They either carry no load, as in monumental designs, or, as in the columns of a Grecian portico, they carry only the static load of an entablature, which by its weight as well as its connection with the mass of the building, really adds to the stability of the supporting columns. The height of Grecian columns varies from 6 diameters in the Doric, to 10 or 11 diameters in the Corinthian, while the ancient obelisks are found to vary in the height of shaft between the limits of 9 and 11 diameters.

But in any stone structure designed to resist applied forces which are not vertical, we shall find the relative height much diminished. A retaining wall of first-class masonry against dry sand, can have a height of only three times its thickness, if without surcharge, or of only twice its

thickness with a surcharge equal to half its height. A masonry dam of dressed granite cannot have a height greater than from once and a half to twice the thickness at the base. It is quite evident from these proportions, that the material is massed together for the sake of its weight, so that it may act as a counterpoise against the external pressures, while the strength of the stone hardly enters into the consideration, because it is evidently so greatly in excess of any possible requirements.

Lighthouses exposed to the force of the waves are less than three diameters high to the top of the masonry.

Smeaton's Eddystone lighthouse, on a base of 26 ft., is 68 ft. high, or 2.61 diameters.

The new Eddystone, now building, on a base of 35′.5, will be 116 ft., or 3.25 diameters.

The Bellrock lighthouse, on a base of 42′, is 115 ft. high, or 2.75 diameters high.

The Wolf Rock lighthouse on a base of 41′ 8″, is 116′ 4¾″ high, or 2.80 diameters.

The Minot's Ledge lighthouse, on a base of 30 ft., is 80 ft. high, or 2.67 diameters.

The Spectacle Reef lighthouse, on a base of 32 ft. is 93 high, or 2.91 diameters.

These structures are most carefully constructed as to the bond between stones of the same course by elaborate dovetailing. In some instances the beds of the outer stones are also dovetailed, while dowelling is common in all of them. In the Wolf Rock, and some other lighthouses of the same class, the first and second courses are bolted to the rock with bolts split and wedged at each end, the holes being made slightly conical. But it is admitted by the builders that all these devices are "chiefly useful in the early stages of the progress of a work, when it is exposed to storms, and before the superstructure is raised to such an height as to prevent seas from breaking right over it." Undoubtedly the dovetailing of the beds adds some resistance to an extraneous force which is about to tear the courses apart—so does the adhesion of the cement—but any stability thus gained is due to the tensile strength of the material, a kind of strength in which stone is comparatively deficient. It is stated by Mr. Douglass (Proc. Inst. C. E., March, 1870) that when "blocks of granite are put together in this manner with Portland cement it is found that the work is so homogeneous as to be as nearly *as possible* equal in

strength to solid granite." When it is remembered that the inclined faces of the dovetail amount only to two bands an inch wide in plan by three inches deep, running across the bed of a stone about four feet wide, it will be seen that a very small part of the stone is prepared to resist tensile strain, and the adhesive strength of all the rest of the bed must be due to the cement. It is customary to design important structures in stone, so that they shall be sufficiently stable against the assumed assailing forces, without reference to adhesion of cement or tensile strength of stone. Hence the necessity for large quantities of stone. The lighthouses mentioned are built solid for about one-quarter of their height, and with very heavy walls for the remainder. The new Eddystone lighthouse, now building, will contain 69,100 cubic feet of stone, and is estimated to cost $390,000.

The ordinary bridge pier has a height of from 4 to 7 times the base. The proposed piers of the Poughkeepsie bridge show in the drawings a height 6¾ times the base at the neat lines, the height being about 160 feet. In general no thrust comes upon a pier from the action of the truss, but only from such impulses as may be communicated through the truss, as a whole, by the sudden starting or stopping of trains on the bridge, or by the action of the wind. Whatever these impulses amount to, they are communicated to the bridge seat and transmitted by the pier to the foundations. It is against these strains that the pier is really proportioned, since a small percentage of the section of the pier in plan would be sufficient to carry all the static load, although it would not have the requisite stability against thrust. The large bulk of stone thus demanded to carry comparatively small loads, the consequent cost, and in some cases the difficulty of obtaining suitable foundations for mass masonry has led engineers to seek for some substitute. Such, for example, is the pneumatic pile of Dr. Potts, a series of cast iron cylinders filled with concrete or rubble masonry. Another example is Cushing's hollow pile of iron filled with wooden piles. Another, in which a very slender support is necessary to save space, is the iron pillar of various forms supporting the girders of the elevated railroads of New York. These pillars have to resist not only vertical loads, but considerable side thrusts. They are inserted in cast iron sockets, which are bolted to foundations of brickwork, so that they are beams in fact, fixed at one end and loaded at the other, the loads causing both longitudinal thrust and transverse strains. All iron or wooden piers are open to the objection of the perish-

able nature of the material, exposed as it is to the action of the elements. The forms used do not always afford sufficient strength for permanency, except by a free use of material which might appear extravagant. There can be no question but that stone is the most desirable material for bridge piers in any situation, provided that the size and cost of a pier can be brought within the necessary limits in a given case. It is therefore a pertinent inquiry how may the size and cost of masonry piers be reduced without a sacrifice of their stability. To answer this question is the object of this paper.

In the first place the size of a pier may not be reduced in any considerable degree by improving the quality of cement used. For though the quality of cement should by no means be neglected, yet it is the universal judgment of engineers that whatever strength may be imparted to a structure by the cement should be omitted from the calculations of its stability, allowing the adhesion to furnish an additional and somewhat uncertain margin of safety.

In the second place the desired object is not to be attained by the use of dowels or metal clamps between the stones of adjacent courses. For, as these are usually inserted, they are inert, nor can they offer any tensile resistance until they have been somewhat stretched by the incipient opening of the joints which they are designed to protect. They are therefore effective only when the structure is on the point of rupture. Their use presupposes a state of tension in a portion of the bed joints which is not compatible with a true stability, for, if it were, then might the adhesion of the cement be taken into account also.

In the third place, no advantage is to be gained by any system of dovetailing between the blocks, since the dovetails are only effective against tensile forces, which should not be permitted in stone structures. Moreover, as in the case of clamps, the adhesion of good cement affords more resistance than the dovetails. Mr. John F. Bourne states in his report on the construction of the Roman Rock Lighthouse, at the Cape of Good Hope (Proc. Inst. C. E., Nov. 1868): "When well made, the Portland cement soon becomes as hard and tenacious as the stone itself (granite), entirely dispensing with the necessity of dovetailing, which could only be of temporary service."

Finally, a monolithic structure is out of the question, owing to the labor and expense of securing and transporting stone shafts of the necessary magnitude, and the difficulty of attaching them so rigidly to

their foundations as to permit the transverse strength of the stone to be developed. Aside from these objections, it is doubtful if many engineers would be willing to risk an expensive superstructure upon the transverse strength of any stone support. Whenever a pillar has been required to withstand a considerable transverse strain, it has been made of some other material than stone.

In general, it may be said that no dependence is to be placed on any method which develops either a tensile or transverse strain in stone; and it may be formulated as a maxim that no stone structure should be subjected to any lateral strain which may not be resisted by the pressure on the beds of the several courses, producing friction as against sliding, and a moment of stability as against overturning. This being granted, it follows that, if by any means the normal pressure on the beds can be increased, the stability of the structure will be augmented; or conversely, if in a structure of given stability, we can supplement the force of gravity by some other available force producing vertical pressure, we may reduce the given amount of masonry without impairing the stability.

Suppose, then, that we add to the pressure due to gravity a pressure due to the elastic tension of a steel rod which has been placed vertically in the masonry, and stretched nearly to the elastic limit. Let the rod be anchored in the foundation, passed up through the core of the masonry, and put into a state of tension by a nut at the top. Its tensile force is now exerted upon a washer, which in turn presses upon the masonry with an equal force, and the pressure is transmitted through every joint to the foundation. We now have the benefit, not only of the attraction of gravitation between the earth and the stone blocks, but also of the molecular attraction between the particles of the steel rod, both forces acting to produce stability, and both being permanent in their nature, while the proportion of parts may be such that the pressure due to molecular attraction may be far the greater of the two. Observe that a rod in the condition described is neither a dowel to prevent sliding, nor an ordinary clamp to limit the extent of motion after rupture of the joints begins—it is no mere passive resistant. On the contrary, it is the source of a perpetual static pressure, acting upon the pier in which it is placed precisely as does the attraction of gravitation (since it passes through the centre of gravity), but with the additional advantage that its point of application is at the top of the pier, pressing the top stone

equally with the bottom one, thereby greatly increasing the stability of the upper portion, and rendering all clamps and similar contrivances unnecessary.

With such a pressure as this at command we may proceed with confidence to diminish the size of the structure, leaving only stone enough to resist safely the maximum compression to which it may be subjected, and breadth of base enough to afford the necessary lever arm. The ordinary pier thus is reduced to a column, or a pair of columns, one under each truss, with a very remarkable saving in the quantity of masonry, without sacrifice of stability. But the saving in quantity of stone and, consequently, in cost, is not the only benefit derived from this mode of construction. There are several other advantages incidentally growing out of it. The amount of stone is so limited that we can readily afford to use the best quality, and to expend a large amount of labor upon it, also to use the best quality of cement and of any desired richness, thus producing a structure of the very first class, where, according to the ordinary method, only rubble work could have been afforded.

Again, the dimensions of a column in plan will in most instances be within the practicable sizes of single stone, enabling us to dispense with vertical joints, and so adding materially to the strength and permanence of the structure. Vicat concludes, after a variety of experiments, that the division of a column into courses, each of which is a monolith with carefully dressed joints and properly bedded in mortar, does not sensibly diminish its resistance to crushing, but that this does not hold good when the courses are divided by vertical joints. Again, a structure of cubic blocks forcibly bound together by a central rod under tensile strain cannot be shaken to pieces by the jar of passing loads, as the top courses of ordinary piers are liable to be, unless well clamped. Again, the small diameter of the column occupies much less space than the ordinary pier, often a desideratum in a water way or crowded thoroughfare, so that by this method we are enabled to use stone, where otherwise it would be out of the question. Columns reinforced by steel may safely be carried to a height of 12 or 15 diameters, beyond which they are subject to the law governing all long columns, and may fail by flexure rather than by rupture at the base.

The use of metal to fortify masonry is by no means without precedent, although the manner of application has been different. Tie-bars

have been used to receive the thrust of stone arches, as in the Milan cathedral, and some other Gothic buildings.* Bands or chains of iron take the thrust of massive domes, as at St. Peter's in Rome and St. Paul's in London. Smeaton placed chains around the Eddystone tower, to receive the thrusts of the arched floors ; and Mr. Douglass informs us that the upper part of this structure has been strengthened on two occasions, viz., in 1839 and 1865, with strong internal wrought-iron ties, extending from the lantern floor downwards to the solid portion of the tower. Although previously the joints of the masonry in the tower had frequently yielded to the heavy strains imposed on them, and the sea water had been driven through them to the interior of the building, yet since making those repairs no further serious leakage has occurred, and the tower is now in a fair state of efficiency. In all these instances, although the metal appears to have been used merely to *resist* such forces as might come upon it *through the masonry*, yet they are useful as examples illustrating the permanence of masonry depending on the tensile strength of iron for its stability.

The principle of utilizing the elasticity of metal to produce *an applied force* for increasing the stability of masonry, as described in this paper, appears to be a novel one. A description of some columns erected by the author in 1878, upon this principle, may be of interest in this connection.

It was desired to erect an iron bridge in two spans of 97½ feet each, across the Presumpscot river, at Cumberland Mills, Maine. (See Plate XLVII.) This stream, which is the outlet of Sebago Lake, is very rapid, and is utilized at several points for water power. It is subject to sudden and violent freshets. The site of the bridge is just below the dam of the Cumberland Mills Company, and upon rapids descending at the rate of about 2 feet in 100. The bottom, at this place, is a mass of ledge rock, which, fortunately, in time of low water, forms a small island at the site of the pier. This enabled the work of preparing the foundation to proceed without interruption from the water. The pier consists of two columns, one under each line of truss, each 2 feet square, and 14 feet high, and entirely independent of each other. A vertical section of one of the columns is shown (Fig. 1, Plate XLVIII). Each foundation was prepared by cutting a place 2 feet square in the rock, and dressing it to a fine and level bed. At the centre of the square, a hole 4 inches in diameter and 30 inches

* Cadell's Journey through Carniola and Italy. Vol. II, p. 77.

deep, was sunk with a Wood's steam drill. The hole was enlarged at the bottom to about 6 inches on one diameter, giving an oval section. The enlargement was confined to the lower 10 inches, and was done with hand drills shaped purposely for this work. The hand drill was kept up to its place by a cast iron cylindrical rest, 3¾ inches in diameter, which was dropped down one inch at a time, as the work of enlarging proceeded. The hole was then calipered at every inch in height, and a wrought iron wedge 14 inches long was forged, of such size and shape, that it would spread the rod so as to exactly fill the hole. The rod was of Bessemer steel, 3 inches diameter, and divided at the lower end by a longitudinal channel, cut through it, 3-16ths wide, and 18 inches long. About a quart of thin paste of clear Portland cement was poured into the hole in the rock, and the rod immediately lowered into it, with the point of the wedge sticking in the jaws. The rod was then driven home over the wedge. with a 450 lb. hammer, having a five foot fall. The hammer was a piece of annular cast iron, sliding loosely on the rod. Its blow was received on two oaken blocks firmly clamped to the rod by four bolts, About twelve blows were required to drive the rod to the bottom of the hole. The upper end of the rod, on which a screw thread had been cut, was meantime held in its true position by a notch in a plank attached to the scaffolding. The remaining space in the rock about the rod was filled with a mixture of Portland cement, iron filings and sal-ammoniac. with water. This was allowed to set four days before laying stone. The stone blocks were of granite, taken from the Yarmouth quarries, near Portland. They were from 18 to 28 inches in thickness, and were finely dressed on two beds so as to make a joint not exceeding one-eighth of an inch. The sides were left with the natural or rock face, only the corners being pitched off to a line. Each block was perforated with a 4 inch hole, by the same rock drill. When the hole was half through, the block was turned over, and the hole finished from the centre of the opposite bed. Each stone, after being carefully cleansed with water, was lowered down over the rod, and set in a thin paste of Portland cement and sharp sand in equal parts. The annular space between the rod and stone was filled with perfectly dry cement powder, the object of this being to protect the steel from rust, without permitting any adhesion between the rod and stone. Upon the top stone was placed a cast iron washer, 9½ by 14 inches, having a central boss, the upper surface of which was turned down smooth. The washer was laid in cement, and a steel nut was

screwed down to a bearing. The nut was then turned still further, so as to stretch the rod twelve-hundredths of an inch. The free length of rod being 14 feet, if we assume the co-efficient of elasticity to be 28 000 000, the strain in the rod is $\frac{0.12 \times 28\ 000\ 000}{12 \times 14} = 20\ 000$ lbs. per square inch. A small set screw was then placed in one side of the nut to prevent the possibility of its ever turning, and the column was complete. A third column was required at one end of the bridge, but otherwise the bridge was supported on some foundation walls of adjacent buildings. The total quantity of stone in the three columns is less than 6 cubic yards.

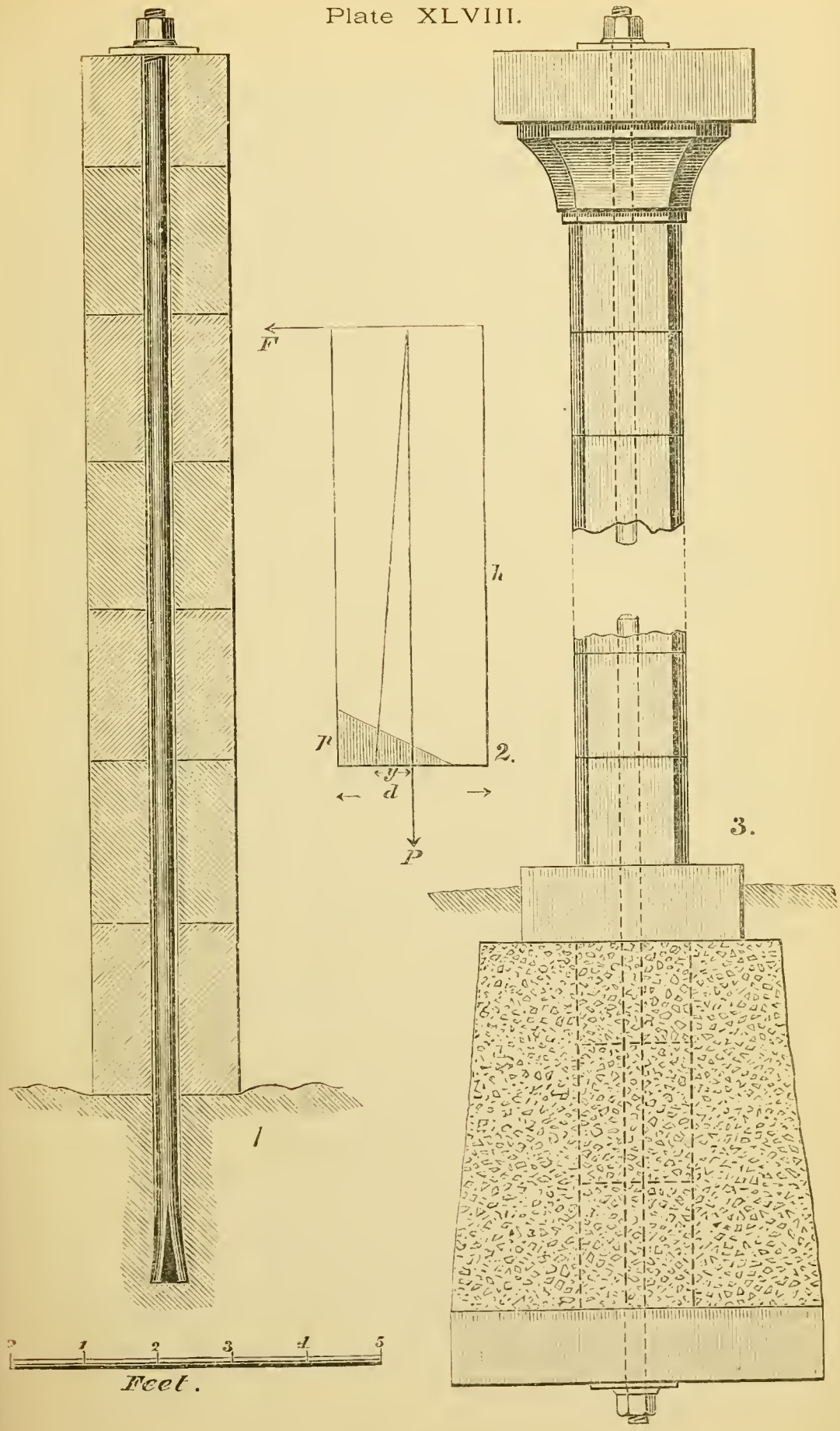
The stability of a column built in this manner is calculated in the same way as for ordinary masonry. We have the weight of the stone and of the load on the column, combined with the pressure due to the tension on the rod, forming a vertical force, which, multiplied into a suitable lever arm in the base, produces a moment of stability; and this must sufficiently exceed the moment of the extraneous forces. But on account of the limited area of the beds it becomes necessary to consider also the compressive strength of granite. Gen. Gillmore gives, as the result of his experiments of fifty-five samples of granite in 2-inch cubes from various sources, for the

Least crushing strength	per square inch,	on bed,	9 450 lbs.
Greatest "	"		24 040 "
Average "		(55 specimens)	16 423 "

He also shows that the strength per square inch is much greater in cubes of larger size. Probably the average crushing strength of large blocks used in a column would not be less than 20 000 lbs. per square inch of bed, one-tenth of which may be used as a safe compressive s rength.

If a column (Fig. 2, Plate XLVIII) of height h is subjected to a horizontal force, F, at the top, the moment at the base is Fh, and for equilibrium with the vertical pressure, P, we have $Fh = Py$, in which y is a variable lever arm measured from the centre of the base to the centre of resultant pressure, and varying directly as F. In the calculation the weight of the column is assumed to be applied at the top, and the assumption is on the side of safety. The maximum value which may safely be allowed to the lever arm, y, will determine the maximum force, F, which the column may safely resist. In ordinary masonry of good quality, subject to side pressure, the practice is to allow to y a maximum value ranging from $\frac{1}{6}$

Plate XLVIII.



to $\frac{3}{8}$ths the diameter of base. We may assume, therefore, $y = \frac{d}{4}$ for a maximum safe value in a column without vertical joints, and reinforced with steel, provided that this position of the resultant does not induce an unsafe pressure at the edge of the joint. In some respects this column resembles an arch of stone voussoirs, in which, although the principle of restricting the resultant to the "middle third" is a good one, yet practice justifies allowing to it the latitude of the middle half, provided that the pressure on the intrados or extrados is not thereby carried beyond safe limits.

When $y = \frac{d}{4}$, the diagram of vertical pressure is a triangle extending over three-fourths of the diameter, its area is equal to the vertical pressure P, and its perpendicular p, represents the pressure per square inch at the surface of the column. If we call b the thickness of a rectangular column at the base at right angles to the diameter d, the value of p is expressed by

$$p = \frac{8}{3} \cdot \frac{P}{b\,d}$$

According to this *theory*, one-fourth of the base is relieved from pressure, but there can be no tension on that part since the pressure on the other part furnishes a moment of resistance equal to the moment of the applied forces. Since, however, *in fact* there must be tension on the one-fourth (unless the stone be absolutely inelastic), the tension, if within the resisting strength of the cement will form a small moment, by which the moment of pressures will be reduced; that is to say, the value of the actual lever arm y, is a little less than shown by theory. If the joints were laid dry, without cement, they could only open one-third of the amount of the compression of the adjacent blocks due to a pressure per square inch equal to one-fourth p as found above. So that the "opening" under any safe force F is practically *nil*.

The strain developed in the rod through the nut, in the first instance, is neither increased nor diminished by any external transverse forces which do not exceed the maximum for which the column has been proportioned. In the equation of moments $Py = Fh$, y and F are the variables, and will so continue until y is limited by the size of the column, that is, until $y = \frac{1}{2}d$, when rupture will take place. But under the maximum value of F, y equals only $\frac{1}{4}d$, which requires no change in P to produce equilibrium. The strain of the rod may be supposed to be

replaced by the weight of a heavy body on top of the column, producing the same pressure, without altering the conditions of the problem. The strain in the rod can only be increased by further stretching the metal, and this can only be done by either expanding the stone or opening the joints, *neither* of which can be effected by the maximum safe force F. Similarly the strain in the rod can only be diminished by a compression of stone along the axis of the column, which the maximum safe force F cannot do. We are therefore not concerned about a factor of safety in the rod, but may use its tenacity up to the so-called limit of elasticity. Indeed, there appears to be no good reason for not carrying the strain still higher, for although the permanent set would tend to diminish the effective extension of the metal and consequently its tensile resistance, yet within reasonable limits of strain there would be on the whole a gain in efficiency.

Since the permanency of the strain in the rod depends on the unyielding nature of the stone, it is important that the joints be laid in cement, which, as it hardens, resembles stone in its qualities. The use of lead in the joints cannot be allowed, because of the tendency of that metal to "flow" under strain, and so gradually to shorten the column.

It is not necessary to the system that the foundations should be on native rock. An artificial foundation may be prepared in earth or other material, the only essential thing being a continuity of solid stone between the bearing points of the rod, to insure permanency of strain. Fig. 3, Plate XLVIII.

The stability of the column described is found as follows :

Stone, 56 cubic feet × 165 pounds =	9 240	pounds.
Bridge, 97.5 feet × ½ × 800 " =	39 000	"
Steel, 7.07 sq. in. × 20 000 " =	141 400	"
Total.....	189 640	"
With ½ foot lever arm, moment of stability = 94 820 ft. lbs.		
Live load 97.5 feet × ½ × 2 000 lbs.	97 500	"
Total.....	287 140	"

With ½ foot lever arm, moment of stability = 143 570 ft. lbs.

These are taken as the maximum safe moments, the factor of safety being at least 2.

The maximum pressure per square inch on any part of the granite under these moments is 878 pounds, and 1 329 pounds, respectively, by the formula for p given above.

The assailing forces are : *First*, that of the water. Two of the most violent and destructive freshets ever known in that stream have occurred since the columns were erected. The greatest depth of water on the column was 8 feet. This on an inclined bed of 2 feet per 100 gives a calculated velocity of 14.9 feet per second, and a pressure upon a vertical surface at right angles to the current of 724 pounds per square foot. As the column is set with a diagonal parallel to the current, the other diagonal, or 2.828 feet, is the width of column opposed to the stream, but since the faces stand at an angle of 45 degrees, the *effective* width is 68 per cent. of this, or 1.923 feet. This, multiplied by 8 and by 724, gives the total pressure on the column of 11 138 pounds; and this by a lever arm of 4 feet (half the depth) gives a moment of 44 552 feet pounds, which is less than half of the above moment of stability. The factor of safety is consequently over 4. Should the water be 10 feet deep, the calculated moment of pressure would be 83 130 feet pounds, and factor of safety would be over 2.

Second, The impulse from a suddenly stopped train on the bridge.—Estimating the train weight on one span at 97.5 tons, half of which comes on one column, and the brake force at 200 pounds per ton, we have a total horizontal pressure of 9 750 pounds applied at the top of the column. The height being 14 feet, produces a moment of 136 500 foot-pounds, and the factor of safety is over 2 in this extreme case.

The slight and elegant appearance of such columns, when their strength is made evident, renders them particularly appropriate to the support of the modern truss bridge, which is so airy a structure as to make a pier of mass masonry look still more cumbersome by contrast. The principle is applicable, however, to masonry designed for other purposes than piers, such as lighthouses, breakwaters, dams, retaining walls, etc. It is proper to state, in conclusion, that this method of construction is secured to the inventor, Charles E. Hill of New York, by letters patent in Great Britain, Canada, and the United States.

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DISCUSSION ON PAPER CLXXXV.

STABILITY OF STONE STRUCTURES.

By O. CHANUTE, CHARLES MACDONALD, D. J. WHITTEMORE, THEODORE COOPER, R. HERING, CHARLES E. EMERY, and WILLIAM H. SEARLES.

DISCUSSION SEPTEMBER 3D, 1879.

O. CHANUTE.—Granting that all the calculations of strength and stress are correct; granting that the construction was perfectly done, and that in the case described in the paper the rod was not drawn up into the dovetailed hole in the rock at the bottom, the $\frac{12}{100}$ (less than $\frac{1}{8}$) of an inch, which the nut was screwed down at the top, the effect of which would be to destroy the initial tension which is estimated by the author at 20 000 pounds per square inch; granting that the tension put upon the rock at the base has not cracked it, and so relieved the rod; granting also that changes of temperature have no effect upon the rod, while we know that if it were in the open air it would be exposed to variations of 150 degrees, which would expand a rod 14 feet long $\frac{15}{100}$ of an inch—it yet seems difficult to see any extended application for this ingenious method of saving masonry.

The instances where solid rock is found at or above the surface of the water, just where we want to locate bridge piers, are, as we know, exceedingly rare. The rock, if rock there be, is generally overlaid with some other material.

Even if this be only water, it would be difficult to make a good job of dressing off the bed for the pier, and drilling the dovetailed hole, say at a depth of 10 feet, especially if there should be a current, and there would be further trouble in stringing the stones accurately upon the rod, after it was anchored.

In fact, the difficulty seems to be to get the composite column into place so as to render it efficient, as this involves making it fast to something at the bottom. We cannot drive it down through the mud like a pile ; we cannot well sink it through sand like a pipe, by a jet of water, as was done by Mr. Macdonald at Coney Island ; and we cannot excavate inside of it, as in a cylinder.

We can, to be sure, put down a coffer dam or a caisson through the overlying material, and, if not too deep, pump it out, and fit the column to the rock ; but in that case the saving in masonry is likely to be more than made up by the foundation expenses. Or we may drive a pile platform under water, cover it with a grillage, and set the column upon that ; but it will then be difficult to connect the column efficiently with the foundation, and the stability against a side blow is likely to be that due to the friction on the bottom—due to the weight alone.

This friction, if the column rests upon stone, will be 60 per cent. of the incumbent weight. If it rests on timber it will be 40 per cent. Now, in the case described, the weight of one column, and of the portion of the bridge which it carries, is stated to be 48 240 pounds ; so that if it rested upon the rock, instead of being anchored to it, its stability against a side blow would be equal to 28 944 pounds, while the thrust of 8 feet of water is estimated by the author at 44 552 pounds. If it rested on timber the stability due to the friction at bottom would only be 19 296 pounds.

Charles Macdonald.—It is difficult to see how the system proposed can be carried out in practice with economy.

If the only object of the steel rod is to "supplement gravity," the same result could be obtained at less expense by simply adding dead weight upon the top of the column, in which case the practical questions referred to in the discussion, as resistance to impact, pressure of ice or floating timber would still have to be met. These and other considera-

tions would probably put this system outside of what may be called staple methods of construction.

D. J. Whittemore.—The stability of masonry of this kind depends on the strain imparted by the steel rod remaining always constant. This I cannot conceive to be practically possible. With a variation of temperature of say 90° Fahr. the unequal dilation of the two materials, granite and steel, would materially change the value of stress imparted by the steel rod.

I cannot conceive that the anchorage into the bed rock in the manner specified to be such as would resist the desired strain for any considerable length of time. In my opinion, the vibration imparted to the columns by winds upon, and traffic over the structure, would in a short time cause such action at the anchorage as to permit the rod to move the $\frac{12}{100}$ of an inch, thereby relieving the pressure intended to be exerted by the rod.

It would be interesting to know whether more than the ordinary appliances were required to turn the nut at the top of the three inch rod to procure the alleged strain of 141 300 lbs.

Theodore Cooper.—The columns described in this paper may be applicable in particular localities, but that they should ever be able to replace ordinary pier construction to any great extent, appears very doubtful.

The author states that the rods in the columns under the bridge over Presumpscot river, were given an initial strain of about 20 000 lbs. per square inch, but does not state whether this was done after the bridge was fully loaded or not. If done previously to the imposition of the weight, the rods would have little or no strain, upon the passage of a load, when it needs its stability against the forces due to this train. For he states the total strain on the column from the rod to be 141 300 lbs. and the strain due to the load (dead and live) to be 136 500 lbs.

In his consideration of the "assailing forces," he considers the pressure of the water against the surface of the column only—and gives no consideration to floes of ice, rafts, boats and floating flood trash; few American rivers or streams are free from some of these, and we think no structure can be considered stable which is not prepared to resist the blows or pressures due to such bodies.

He finds a factor of safety for these particular columns of 4 and 2 for 8 and 10 feet of water respectively—with a surface exposed to pressure of 1.925 feet × by the depth of water.

It would not require much ice or floating logs or timbers to increase this surface sufficiently to reduce his factor of safety to nothing.

If ordinary substructures in running streams were calculated upon the same data as the author has adopted, their dimensions might be reduced to very small ones, but few engineers would like to venture upon such proportions.

For locations free from water, it is very questionable, unless the proper data for calculating the cost of work upon these columns is furnished, if iron columns would not be far cheaper and better adapted for the purpose, especially when the facility for bracing cheaply is so easily obtained.

R. Hering.—This paper is very interesting, and I believe the novel idea illustrated may be applied with advantage in certain cases.

Fearing that the author may be subject to some misinterpretation, I would like to emphasize an essential point which, as I think, has not been made sufficiently clear.

He says that the tensile strain of steel rods compressing the structure may "supplement the force of gravity."

This is only conditionally true, and upon the proper disposition of this strain will depend entirely the success or failure of the pier.

The moment of stability is assumed to be the weight of the stone plus the pressure due to the tension of the rod multiplied into a lever arm equal to one-fourth of the base. This can only be true, if the pressure due to the rod is an *applied* or *motive* force, acting like gravity. What, however, is the condition of the strain in the rod? There is a force acting upwards against the direction of gravity of precisely the same intensity as the one acting downwards, as in the case of a block which is simply compressed by the action of such rods, but which, when set upon the ground, would certainly not have its stability against overturning increased thereby,

An essential consideration must be observed, which is, that, in order to obtain an applied or motive force, such as is brought into the calculation, it will be necessary to neutralize the force acting upwards. This can only be done by anchoring the rod in the foundation to such an extent that this entire upward pull will be safely resisted by it, *i. e.*, neutralized and prevented from acting in opposition to the downward force which we desire to utilize.

An anchorage furnishing such resistance is indispensable to the success of the plan, and it seems to me that the author has not sufficiently insisted upon this, and therefore might cause misapprehension. The only reference is made, when he says, "let the rod be anchored in the foundation," but to what extent this must be done, is not mentioned.

In Fig. 1, Plate XLVIII, he describes an executed example, and says that a hole was drilled into the rock 30 inches deep to anchor the rod, but nothing is said about the capability of the rock to withstand a lifting tendency 141 300 lbs. (of course before the weight of the column is on it), although this fact is essential to the stability of the described piers, when subjected to the extraneous forces which he assumes.

A further remark might also tend to mislead the reader on this point, when Mr. Searles says that heretofore metal was "used to merely *resist* forces coming through the masonry," but that the present novel case is (without giving the conditions) a "principle of utilizing the elasticity of metal to produce an *applied force* for increasing the stability of masonry."

Nor does he allude to the importance of this question, when he says that "it is not necessary to the system that the foundations should be a native rock," but that "an artificial foundation may be prepared in earth or other material," and adding, "the only essential thing being a continuity of solid stone between the bearing points of the rod."

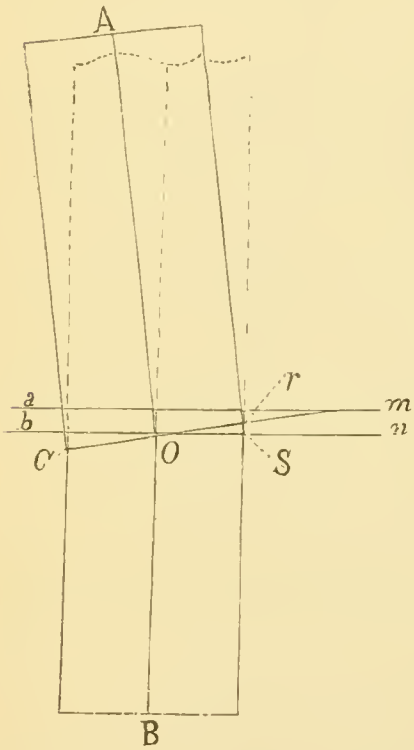
It is questionable in my mind whether this method will be economical in any case, except when the foundation is solid native rock, for the same amount of masonry which is saved in the upper part of the structure by utilizing the *downward* strain in the rod as a motive force would generally have to be built into it as a foundation or anchorage to get weight enough to resist the *upward* action of that same strain.

The only disadvantage I can see in utilizing the elasticity of a rod for the purpose recommended in the paper is the precision with which the true elongation must be ascertained when the rod is finally put under tension, as every hundredth part of an inch corresponds, in Mr. Searles' case, to over 1 600 lbs. To be certain of the exact amount of motion, when tightening up the rod, which is solely due to its extension but does not contain an element due to the compression of the masonry, requires a delicacy of adjustment which is difficult at best, and in many cases may perhaps be impossible.

Charles E. Emery—I have examined this paper with considerable interest, from the fact that it appears to be a practical application of the

principles involved in a discussion in which I was engaged some years since on the subject of initial tension.* I am pleased to state that this previous consideration of the general subject, in connection with the formula in my recent paper on "The Flexure and Transverse Resistance of Beams," enables me to suggest what I think will be accepted as a more complete analysis of the conditions of equilibrium of all columns than that offered in the paper under discussion, and giving results somewhat more favorable to stability.

In figure let *A B* represent one of the columns, and suppose any section to be compressed by the dead load, and an internal rod from a plane in the line *a m* to another in the line *b n*. If now a lateral force be applied at the top of the column, it has no tendency to increase or decrease the *total* vertical force, but, as in any case of transverse resistance, equal and opposite forces must be developed on opposite sides of the column to resist the lateral moment. Were the column homogeneous and not under vertical strain, the movement due to the moment, as well as the strains developed, would be represented by two triangles, *b o c* and *r o s*, and the initial strain does not change this representation, for such strain is simply increased on one side by the forces represented by the triangle *b o c*, and decreased on the other by the forces represented by the triangle *r o s*, the moment being balanced by the difference in strain as before. So long as the forces produced by the moments on the side last above named are less than



* The discussion referred to was occasioned by an article in the "Railroad Gazette," to the effect that tightening the back braces of a bridge increased the strains on main members when supporting external loads. The contrary appeared so evident that I went further than necessary by asserting that it was a general principle that strains due to internal tension or by the tightening of one member upon another were not increased by the application of external loads producing strains of less intensity. This appeared accurate at first sight, from the following illustration: If a spring balance were hung up, and maintained in a state of tension of say 50 lbs. per index, by struts between cross pieces in the rings, evidently any load less than 50 lbs. would not loosen the struts, and hence the strain on the spring would

those due to the initial tension, evidently the strain on the rod will not be altered. The whole structure, including the rod and stone, is, under such circumstances, in the condition of the compressed side of a beam. Before the lateral moment acts consecutive sections of the beam are parallel, and may be represented by the lines am and bn, but on the application of the bending moment such lines converge, and the axis for reference corresponding to the neutral axis, rapidly approaches the column, but should in general remain outside. The lateral force may, however, be increased until the neutral axis moves within the section of the column, in which case the vertical lifting force due to the moment has overbalanced the downward pressure, and strain is thrown upon the rod in addition to its initial tension. When, however, the strains from the moment are kept less than the original tension, the former may be separately considered. In my paper referred to,* §43, it is shown that the centre of effort of the forces either side the neutral axis for a rectangular section are situated at distances r_0 and r_1, from the axis equal respectively for a homogeneous material to $\frac{2}{3}$ the semi-diameter. Using my notation of $M =$ the bending moment and N the longitudinal force due thereto, which acts in opposite directions on the two sides of the axis, we have for my paper (Eq. 20) $M = N(r^0 + r_1)$, or using Mr. Searles' notation as far as applicable

$$(1)\quad Fh = \frac{2}{3}\ Nd$$

in which $F =$ the lateral force at the top of the column, h the hight, and d the diameter of the column. Hence

$$(2)\quad N = \frac{3\,Fh}{2d}$$

If P represent the total vertical stress derived from the dead weight and the tension on the rod, as explained previously, the outer joint will not open, or the tension on the rod be increased, so long as $N < \frac{P}{2}$, and

not be increased until the external load produced strains greater than the internal tension of 50 lbs. Mr. J. F. Flagg, however, called attention to the fact that this would be true precisely only when the struts were inelastic, when Mr. E. S. Philbrick pointed out that the reacting elasticity would in general soon exhaust itself, the sections of struts being usually larger than those of ties, and that, therefore, the strains would only be increased slightly by external loads. All these suggestions together showed the true solution of the question; but it required a mathematical calculation to ascertain exact values which I expected to present before this, and which will show the original statement practically true, viz., that tightening the back braces of a bridge as constructed (in practice) does not increase the strain on main members under external loads, though the proposition, as a general principle, requires the modifications referred to.

* Flexure and Transverse Resistance of Materials. CLXXXI. Vol. VIII. June. 1879.

for this condition we have from equations (10) and (17) of my paper for the unit strain due to the lateral moment at the edge of a square column,

$$(3)\ f = \frac{4\,N}{d^2} = \frac{6\,Fh}{d^3}$$

but as this is in addition to the initial strain on one side of the column, we have for the maximum unit strain

$$(4)\ f^1 = \frac{4\,N}{d^2} + \frac{P}{2d^2} = \frac{8\,N + P}{2d^2}$$

For the most extreme example given by Mr. Searles, viz., a force $F =$ 9 750 lbs. acting at a height, $h = 14$ feet with diameter, $d = 2$ feet, we have from (2)

$$(5)\ N = \frac{3 \times 9\,750 \times 14}{4} = 102\,375 \text{ lbs.}$$

$$(6)\ \frac{P}{2} = 143\,570 \text{ lbs.}$$

Hence in this extreme case $N < \frac{P}{2}$ so the joints will not be opened or the strains on the rod increased. From (4) the maximum strain per square inch of stone under above conditions is $f^1 = 960$ lbs.

When the strains are applied in the direction of the diagonal of the section, as would in general be the case in the example given, the distance between the centres of effort $(r_0 + r_1) = .707\ d$, so the several equations above take the following forms :

$$(2a)\ N = 1.414\ \frac{Fh}{d}$$

$$(3a)\ f = \frac{6\,N}{d^2} = \frac{8.484\,Fh}{d^3}$$

$$(4a)\ f^1 = \frac{6\,N}{d^2} + \frac{P}{2\,d^2} = \frac{12\,N + P}{2\,d^2}$$

Hence in the particular case $N = 96\,506$ lbs.;

$$f^1 = 1\,254 \text{ lbs.}$$

That is the stability is greater than before, but the maximum strain per unit of area of the stone is also greater, though within safe limits.

In any case as soon as N becomes greater than $\frac{P}{2}$ increased strains are thrown on the rod and the factor of safety is limited by its ultimate

tensile resistance or the ultimate crushing resistance of the stone when the moment arm is reduced to the semi-diameter or a little less. It will be seen then, that so long as the lateral moment is not sufficient to overcome the initial tension the stability is greater than estimated though the ultimate resistance is as stated in the paper. These calculations are independent of the moduli of the material, but evidently depend upon the original adjustment and approximate maintenance of the initial tension under variations in temperature and other practical conditions mentioned by the other speakers.

The above equations are equally applicable when the stability is produced by dead weight only, and when the column is bent, forming an arch.

William H. Searles.—Inasmuch as the steel rod is enclosed in the granite, and since steel conducts heat some 20 times more rapidly than granite, the two will be of sensibly the same temperature at all times. If the column is heated to 120° Fah. on the sunny side, its temperature may be 80° on the opposite side, giving an average of 100° for the heart of the column, and for the steel. If the column was erected at a temperature of 70° we have only 30° of expansion to consider.

The expansion of steel, per degree, is.....	.00000600
The expansion of granite, per degree, is.....	.00000438
Difference is.....	.00000162
and for 30°.....	.0000486

which corresponds to a change in strain of 1 360 pounds per square inch. Therefore, in the extreme heat the rod will be relaxed .068 of its initial strain of 20 000 pounds per square inch, or .045 of an initial strain of 30 000 pounds which is now adopted. For extreme cold the tension is increased, and the stability likewise, without, however, endangering the steel by undue tension.

The coefficient of elasticity of granite is probably about one-sixth that of steel, while the section of the stone in the example cited is 80 times that of the steel; hence under equal strains the compression of the granite will be .075 the extension of the rod. If afterwards a load is imposed, equal to the strain in the rod it will not relieve the rod of more than .075 of its strain. As the live load and horizontal force were both arbitrarily assumed for illustration, this refinement of correction was

omitted. It is of importance, however, when calculations are to be made upon exact data.

The parties for whom the columns described were built, were positive that the chances of impact by any heavy floating bodies were exceedingly remote; consequently no special provision against impact was made in this case. So, too, the depth of eight feet of water is the absolute maximum—the depth of ten feet is imaginary. We may not be able to decide from theoretical considerations what amount of impact such columns would safely resist; but it could hardly be less than that of any iron columns that might be adopted in their place. A granite column is now building at Mott Haven, N, Y., which is to be tested for impact as well as for other kinds of strain. It is hoped that these experiments will throw considerable light on this subject.

It ought not to need saying that the design of these columns, both in elevation and plan, can be varied *ad libitum* to meet the requirements of special cases. Thus, quite a heavy pier may be built up to the limit of the flood or ice line, to resist impact and extraordinary pressures from the strain, and yet be surmounted by a slender column of stone to carry the superstructure ; the whole being reinforced by a steel rod extending from coping to foundation, and affording, according to its size, any amount of stability desired.

It is, of course, obvious that when the rod is anchored in solid rock the rock must be able to resist the pull of the rod, otherwise the column in overturning would carry away a portion of the solid rock with it. The surface of a right cone 30 inches high, and having 30 inches base, is 1 580 square inches, among which the strain of 141 400 pounds being divided, gives 90 pounds per square inch as the strain on such an imaginary inverted cone in the bed rock when the rod is 30 inches deep.

In case of soft rock which might not resist the direct pressure of the rod, a larger piece of iron may be anchored securely in the rock to gain adequate resistance, and the rod screwed into this. A combination of nut and lewis pieces accomplishes the same purpose at any desired depth.

The stretch of the rod in fourteen feet would be 18 hundredths of an inch for a strain of 30 000 pounds, now adopted, and of course twice as much in a 28 foot column, so that the taller the structure the greater will be the security against a loss of tension in the rod.

When the bed rock is submerged or overlaid with other material much smaller coffer dams may be employed than for ordinary masonry,

and these may generally be left in place and filled with concrete around the columns, giving additional stability. Or a crib may be sunk to the rock filled with concrete, and a column complete in itself may be bedded in this material to a proper depth without going to the bed rock with the stone.

When the foundation is of sand, the columns may be built on a staging out of water, and afterwards sunk by the water jet process to any desired depth, the water-pipe passing down outside of the column and discharging at a central point beneath it, and afterwards being unscrewed and detached. Columns for this purpose may be 16 or 18 inches in diameter.

When the column is built upon earth, as in Fig. 3, Plate XLVIII, the foundation may be given any depth and bulk necessary to insure stability, while the granite core running through it to the bottom secures the resistance required for the steel, and enables the stone column to utilize more fully the stability of the foundation than an iron column generally can do.

Mr. Emery, in his discussion of strains, assumes the column to be a homogeneous beam, which it is not. While his formulæ seem to be applicable so long as the centre of pressure is within the middle third, yet inasmuch as we are mainly concerned with the maximum strains which may carry it beyond this limit, I prefer to consider the column as a voussoir arch, of infinite radius. The shaded triangle in Fig. 2 represents the reaction of the foundation at the lower joint. Its area represents the vertical force P, and its centre of gravity is over the point where the centre of pressure intersects the base. When $y = \frac{1}{4} d$, the base of the triangle $= \frac{3}{4} d$, and its area $= \frac{1}{2} p \times \frac{3}{4} d = P$ for a unit's thickness of column; whence, multiplying by the thickness b, we have

$$p = \frac{8}{3} \cdot \frac{P}{bd} \text{ as before,}$$

for the maximum unit strain in the granite at the surface of the column, when $y = \frac{1}{4} d$. Under these conditions the strain in the rod is not increased.

Most of the objections suggested will apply in a greater degree to iron columns, while the stone column has in its favor no limitation as to size, an increasing stability with increasing load, absolute durability of material, and no expense for painting or repairs. Lugs of metal may be inserted between stones during construction, for attaching braces,

&c., though braces are quite unnecessary, since the columns may easily be designed to be self-sustaining without them, and the trusses should be.

The question of cost is outside of a technical consideration of the principle involved; but since it has been raised it will be sufficient to reply that the cost of these columns is found to be not only less than that of ordinary masonry, but also within the cost of iron supports of equal strength when their necessary foundations are included in the estimate.

ERRATA.

Paper CLXXXIII. Transactions, Vol. VIII. August, 1879. Schmidt on "The South Pass Jetties."

Page 190. Third line from bottom, for 1879, read 1878.

" 204. Eleventh line from bottom, for *slope*, read *slopes*.

" 206. Top line, omit the word *long*.

" 206. Bottom line, for *cone*, read *core*.

" 208. Eleventh line from bottom, after *inch boards*, insert *as a flooring*.

" 219. Seventh line from top, for *when* read *where*.

" 223. Thirteenth line from top, for *dykes*, read *dyke*.

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NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CLXXXVI.

(Vol. VIII.—October, 1879).

THE USE OF STEEL FOR BRIDGES.

By THEODORE COOPER, C. E., Member of the Society.

PRESENTED AUGUST 2D, 1879.

The substitution of steel for iron for bridges has become a prominent feature of discussion among engineers and bridge builders.

Some are still skeptical upon the propriety of using it; others are sanguine enough to believe that all that is now necessary, in reference to the introduction of steel, is to use it.

The problem, however, is not so simple, although it is no doubt true that the more we use it the better will we know how to use it.

Steel must enter upon a struggle for precedence with iron, somewhat similar to that which iron has been undergoing, with reference to wood for the past forty years, and will undoubtedly come out in the end as victorious.

It will be instructive and interesting to look back upon the past development and history of American bridge building.

The first characteristic American bridges were built almost exclusively of wood—iron only entering into some of them in the form of straps and bolts. Wood was cheap and ready at hand; it was easily worked into th.

required shapes by the skilled labor found at all points; and all the work could be performed upon the building site.

About 1840 an advance was made toward a further use of iron and a simplification of the labor of framing the wooden portion by the introduction of plain iron rods with nuts at each end, for the tension members of the web system.

This stage brought us to the perfection of our styles of wooden bridges—the Howe bridge—a bridge which still disputes with iron the right of existence in many parts of our country, due to its low first cost and facility of construction.

Its merits of cheapness and readiness of construction would have prevented for some years a further advance towards our present styles of wrought iron bridges if the factors of rapid decay and liability to burn had not entered into the question.

Iron, with reference to its application in any other form than as simple rods, was a new material. The questions of its first cost, the reliance which could be placed upon it for any new adaptation, the forms of its details, the mode of working it into proper shapes and the manner of obtaining accurate dimensions were all to be met.

Gradually and slowly, in the hands of the able engineers and builders who had undertaken this specialty, our present well developed and reliable styles of wrought iron bridges were accomplished facts.

Only those who have been engaged in the building of iron bridges from the beginning to the present day could give a full and correct account of all the thought, anxiety and patient experiment gone through with to fully develop the present forms in use in wrought iron construction.

At first cast iron was almost entirely used for compressive members and for making the connections of the several members. The old wooden forms were closely adhered to, not only in reference to the general forms of the trusses, but also in the mode of connecting the parts.

The tension members were made of wrought iron, but it was some years before they assumed our present form of eye bars. In some of the earlier bridges the lower chord was built up very much like the chords of the wooden bridges—it being formed of long flat bars welded in one length and combined together like a wooden chord—the connections to the posts and web rods being by means of angle blocks of cast iron, which connected to the lower chord by lugs fitting into notches cut into these bars.

In others the lower chord was made of long loops, link shaped, made by bending and welding together the ends of a long square bar. These connected to trunnions cast upon the foot of the posts. The use of wrought iron pins was afterwards introduced.

In others a nearer approximation to our present form of eye bars was made by looping over the ends of a square bar and welding these ends to the body of the bar; thus making what is still used in places, and is called a bar with looped eyes.

The room taken up on a pin by these square bars created the demand for flat bars which could be packed closer together. This necessity led to the development of a method of making a flat eye bar such as is now used.

The cast iron gradually, but stubbornly, gave way to improved forms of wrought iron, and now we have true wrought iron bridges.

Their construction has demanded large investments in workshops with special plant, created new demands upon the capacity of rolling mills and developed a special class of workmen. Iron bridge building is now a special branch of engineering science. It is not a knowledge of strains alone that is necessary to enable one to design successfully a wrought iron or steel structure. Where such structures are thrown open for competition the structure which costs the least and satisfies the requirements, as regards the quality of the material, ability to meet the strains, method of details and general workmanship, will be the best. The practical designer must have a large experience and a clear judgment of the influence of the several factors which enter into the problem. The theoretical solution of the most economical proportions will be vitiated by the necessity of taking into account the following factors:

1st. The use of such forms and sizes of material as can be obtained in the market.

2d. The possibility of combining these forms into shapes and proportions suitable to the purpose and to the strains they are to resist.

3d. The relative prices of different sizes and forms.

4th. The relative cost of manufacturing these into the required shapes.

5th. The limiting sizes to be used regardless of the smallness of the strains.

6th. The cost of transporting and erecting different designs.

7th. The liability of long and light pieces to be distorted and injured during transportation and erection.

8th. The relative cost of suitably bracing structures of different designs and proportions.

9th. The relative cost of making the connections of the various parts.

10th. The objectionable looseness of a structure carried to a theoretical lightness.

Having thus briefly considered the circumstances governing the introduction and use of iron bridges let us consider what are the prospects of the substitution of steel for iron.

The word "steel" is now used to represent a variety of alloys of iron and carbon modified to a more or less extent by the unavoidable or intentional addition of certain other metals or metalloids, as phosphorus, sulphur, silicon, manganese, chromium, tungsten, titanium, &c., the first four being nearly always present, modifying or intensifying the hardening action of the carbon.

As the engineer applies the finished material, iron or steel, to perform certain duties, whether it be as a bridge, ship, boiler, tool, or machine, where the material has to resist the forces acting upon or through it by its physical attributes, it should be his aim and duty to determine what *physical* qualifications the material should possess to best perform its desired work.

The chemical investigation of the properties of various grades of steel belongs to the chemist and producer of the material. In either iron or steel it is the duty of the Engineer and worker of the steel or iron to specify what are the characteristics, from their field of experience, required, and in no manner to hamper the producer of the material by specifying the grade of ore, kind of scrap, or mode of working. By different methods of working, whether it be in the puddling or smelting processes, or in the manner of hammering and rolling, different results will be obtained from the same ores or same scrap, and equally good material for definite purposes can be made, for the same reason, from entirely different raw material. When any chemical element is present in the product, or any condition of the process is known to give uncertain results, some being good and others bad, the engineer is perfectly justified in demanding, under such circumstances, a more onerous and expensive series of tests or guarantees in order to satisfy himself of the uniformity and reliability of the material.

Neither has the engineer any right to brand any process of manufac-

ture by specifying that only such a process or processes will be allowed. If it is known that steel or iron made by any one or more processes has objectionable characteristics, the specification should be drawn to exclude material with *such characteristics*, thus leaving all manufacturers to improve or vary their product as best they can.

Open competition, upon a clear and well defined specification, will soon develop the best mode of making and the proper chemical composition of the material.

Moreover, chemists and experts in the manufacture of steel are themselves largely at variance upon the influences exerted by fixed proportions of the chemical constituents.

With this explanation, we will confine our remarks to the physical characteristics of steel. The most important of these are the tensile strength and the ductility. These *largely* represent its suitableness for engineering purposes. The range of the tensile strength in steel for practical purposes extends from about that of the softest iron (45 000 lbs.) to four or five times as great. Its ductility (when measured upon a standard specimen eight inches between points of reference) ranges from about 50 per cent to nothing or extreme brittleness.

Within this great range of qualifications an engineer ought to be able to find steel suitable for any structural or mechanical purpose, and will be able to do so when our experience has been sufficiently extended to enable us to determine the kind best suited to our purpose.

In making such a selection he must be governed not only by the *character of duty* which the material must be *adapted to do*, but must also take into consideration its *ability* to *undergo the processes of manufacture* in preparation for its actual use.

In selecting steel for bridge purposes, such a quality of material must be chosen as can stand the processes of rolling into the various shapes demanded; can be bent, cut, punched or drilled, and worked into finished members with the least injury to its structural requirements, and can be handled through all its processes from the ingot till it is a finished bridge without more than ordinary care, (parts of iron structures have frequently to pass through severer tests during the processes of manufacture, transportation, and erection than after they are doing duty as part of a completed work).

Ductility being that characteristic which indicates the relative ability of the metal to flow under a strain exceeding the elastic stress, is there-

fore the property which governs the capability of adjustment to local or internal stresses produced by the various mechanical processes. The ductility is, however, only gained by a sacrifice of the high tensile resistances of the harder steels. In other words, the *full cohesive action* of the material cannot be developed as long as the molecules have the power to move among themselves at a low strain. That this motion of the molecules is governed by a frictional resistance seems very plausible from the following facts :

1. The existence of an elastic limit or point of strain up to which the flow or molecular action does not occur.

2. The great development of heat in the metal during such flow.

3. The increased limit of elasticity and ductility imparted to iron and steel by the "kneading" it receives from the processes of rolling and hammering.

But apart from any theory upon the subject, the fact is well known that great ductility is accompanied by a low tensile resistance, and a high tensile resistance by a diminution or total absence of ductility.

The usual measure for the ductility is the amount of elongation, in percentage, of a certain length of specimen under its ultimate resistance.

As specimens of the same material, in different forms, will give different results, and as the reduction of the specimen is much more rapid in the immediate vicinity of the fracture, it is absolutely necessary to have all comparative tests made upon the same form and size of specimen. It is impossible to make any use, for general deductions, of a large percentage of the tests heretofore made upon iron and steel, from the fact that, even when the details *are* all recorded, the varying sizes and shapes of specimens prevent any comparison. Experimenters all over the globe have recognized so well the importance of this fact, that an effort is being made to establish by mutual acceptance a uniform size of specimen.

A large number of experimenters, and most of the governmental boards in Europe, have accepted or approximated to 8 inches as the length upon small specimens for estimating the elongation. For round specimens a diameter of about ¾-inch, and in flat specimens a width from 1½ to 2½ inches, (the former would seem to be a nearer approach to a comparative test with the round specimens than the latter).

From the result of experience, and experiment made upon steel for use in boilers and ships, where the mechanical processes and strain actions are very similar to those in bridges, it has been found expedient to

limit the grade of steel to that which has the following physical characteristics : a tensile strength between 60 000 and 75 000 lbs. per square inch, and an elongation upon a specimen of 8 inches of 25 to 15 per cent., the more conservative tendency being towards the lower tensile strength. The British Admiralty requirements being as follows : "Strips cut lengthwise or crosswise to have an ultimate tensile strength of not less than 26 tons (58 240 lbs.), and not exceeding 30 tons (67 200 lbs.) per square inch of section, with an elongation of 20 per cent. in a length of 8 inches, the beam, angle, bulb, and bar steel to stand such forge tests, both hot and cold, as may be sufficient, in the opinion of the receiving officer, to prove soundness of material and fitness for the service."

"Strips cut crosswise or lengthwise 1½" wide, heated uniformly to a low cherry red, and cooled in water of 82° Fahr.; must stand bending in a press to a curve of which the inner radius is one and a half times the thickness of the steel tested.

The strips are all to be cut in a planing machine, and to have the sharp edges taken off.

The ductility of every plate, beam, angle, &c., is to be ascertained by the application of one or both of these tests to the shearings, or by bending them cold by the hammer.

All steel to be free from lamination and injurious surface defects." The French requirements are almost identical.

As bridges are composed of various forms of members which have to perform entirely different duties and which pass through mechanical operations of different kinds, let us consider them more in detail.

American bridges are generally built up from the following individual members, most, if not all the mechanical work upon them being done in the shop.

1st. Chord and web eye-bars; round, square or flat bars with a head at each end, formed by some process of forging.

2nd. Lateral, diagonal and counter rods ; bars of a lighter section than the above ; sometimes with a forged eye at each end and a screw adjustment at some intermediate part of the rod. Sometimes without eyes, and having a screw thread on each end. The portion of these rods which has a thread upon it, is upset to a larger diameter than the body of the bar (generally ¼ inch) for a length of 6 to 8 inches.

3d. Floor-beam hangers. These are of various patterns, but most usually are bent loops with screw threads cut upon the upset ends.

4th. Pins.

5th. Lateral struts.

6th. Posts.

7th. Top chord sections.

The last three being columns formed by riveting together various rolled forms; plates, angles, channels, I beams, and some special post forms. Some are square ended, others pin-connected.

8th. Floor-beams and stringers. These consist either of rolled beams, riveted plate girders, or occasionally of latticed or trussed girders.

We will now examine these separately, considering their respective strain duties and the several mechanical manipulations which they must undergo, to see what, according to our *present* knowledge, is the character of steel best suited to their purpose.

1. Chord and web eye-bars. These are tension members, and are of uniform section throughout their body, and have at each end a gradual enlargement which forms the eye for connection to the pins. The work put upon these bars is in forming the eye and boring the pin-hole—the first operation being the only one which can do an injury to the material. Whether a head can be successfully and certainly formed by either the process of upsetting or welding, without injury to the material, is so dependent upon the character of the plant used and upon the quality of the steel, that it remains for *future* tests to satisfy us in regard to this matter.

According to our present knowledge, the process of Mr. Kloman of Pittsburgh, of rolling a bar down in the centre so as to leave a portion at each end of greater thickness from which the head can be hammered or pressed out, seems the most satisfactory. It would, however, be very rash to assert that no other process *may be* developed.

If the eye can be formed upon these bars without injury to the character of the material, and if the length of the bars is not so great as to risk their injury by bending during the process of working, transportation or erection, a comparatively high limit of strength *might* be adopted for them, say 80 000 to 85 000 pounds per square inch. with an elongation in eight inches of never less than fifteen per cent. As the steel to fill this condition would require to be very well worked, it may, for the present be impracticable to obtain so high an ultimate strength with that minimum of elongation, and this elongation is the important factor to be insisted upon whatever the tensile strength may be.

2. Lateral, diagonal and counter rods. These being more liable to be bent in handling, and being subject to a more sudden strain from rapidly passing trains, should be of a more ductile quality than the above. A similar material to the above can be used, as the greater amount of rolling required would increase the ductility, but the elongation should be limited to at least twenty per cent. As steel will not stand long under the sharp grooves of the ordinary forms of screw-threads a change in the form of threads should be made. The bottoms of the grooves should be rounded instead of the truncated V form as now used.

3. Floor-beam hangers. As these receive the direct action of sudden loads, and are so vital to the safety of passing trains, they should also be made of a very ductile quality of steel.

4. Pins. The severest test that these must undergo being from a bending strain, and having to pass through no injurious manipulations, a hard steel could be adopted.

5, 6, 7. Compression members. The natural conclusion of those familiar with the characteristics of different steels, would be that for these members a high quality of steel is most essential; but, as before stated, the mechanical manipulations through which they must pass have also to be considered. The shearing, bending, straightening, punching, planing, &c., through which these members must pass are operations of the severest kind for steel, and could only be justified upon the softest steels. Moreover, frequent cases have occurred (one came recently within my knowledge) where, from derailment of a car, posts have been bent out of shape, and the bridge saved from destruction with its accompanying loss of life, by the toughness of the iron posts. Now, a steel post, whether drilled or punched, would not be able to stand such a test unless it was of a material equally ductile.

8. Rolled beams and plate girders. The material for the rolled beams will be largely governed by the process of rolling into shape. For plate girders the same remarks as have been expressed for compression members would be still more applicable as parts of them are subject to tensile strains ; and steel which has been reduced to irregular sections by numerous holes, whether these holes have been drilled or punched, will not have the same power to resist repeated strains that a uniformly prismatic bar would have.

The necessity of annealing all pieces of steel, whether soft or hard, that have been unequally or locally heated, or locally strained in any

manner by the several processes, has not been mentioned in our consideration of the quality of the steel to be used for the several members of a bridge structure; vital as this process is to a successful result, it will not restore steel that has been incipiently ruptured by careless forging or other mechanical work. The only benefit of annealing is to relax undue local strains. If the steel is so hard as to be cracked at the edges of the holes or shear cuts, or by unequal cooling during the process of forging or rolling, or by cold hammering, however imperceptibly, the strength of the metal cannot be restored by any after process of manipulation. Hence, it is absolutely necessary to keep the quality of the metal down to the point where it cannot be thus injured by the particular processes to be adopted in the manufacture. That after processes will be developed by which these different members can be formed without such severe manipulation is certain, but for the present transition stage we must consider the methods and plant we are now prepared to use.

We have endeavored, in the preceding remarks, to make clear the importance and necessity of requiring a ductile metal regardless of what its tensile strength may be. This ductility must be that of the actual rolled material, and not that of the ingot metal, or samples of the ingot metal worked in a different manner from the material to be used. The condition of the actual forms cannot be judged in any other manner than by taking the actual pieces or proper specimens from them.

The amount of tensile strength that can be obtained in connection with a specified percentage of elongation is dependent upon two factors: one is the chemical composition and the other the amount of work put upon the metal during the forging or rolling. The first, as before explained, is only of importance to the user of the material, as it may impart new *physical attributes*, and these are the means by which he should determine its appropriateness for any particular purpose. If it will not harden or become brittle or treacherous under any condition of heat or work to which it will have to submit, it is unimportant for his purpose what the proportion of carbon, phosphorus or other ingredient may be. Even if he knew the accurate composition, he is still compelled to depend upon his physical tests to be assured of its quality.

The second factor, or amount of work put upon the metal, will be governed by the capacity of the plant by which it is to be worked. Therefore, we cannot expect so large a tensile strength in the heavy

sections as in the smaller ones. Competition will soon develop the capabilities of our manufacturers of steel, when a sufficient demand has been created for a steel with definite characteristics suitable for bridge purposes.

In the meantime, we do not think any bridge builder or engineer is justified in requiring a steel of high tensile strength, unless he has first satisfied himself, by a thorough series of tests, that the steel can be obtained in suitable forms and will stand the required manipulations without injury.

The cost of the St. Louis Bridge was largely increased by a demand for forms and material beyond the capacity of the period ; new plant had to be created, and much time lost by experiments to obtain the requisite parts of the structure. Special cases may occur where the importance of the work will justify the loss of time and the additional expense created by excessive demands, but generally the question of cost will restrict the requirements to the known possibilities. The following requirements for bridge steel should, in our opinion, be the *maximum* as to tensile strength and *minimum* as to elongation demanded, until increased experience proves the safety of changing them. Tests to be made upon the standard form of specimen.

For plates, angles, channels and other shapes an ultimate strength between 65 000 and 70 000 per square inch, elongation not less than 20 per cent. in 8 inches ; limit of elasticity above 35 000 pounds per square inch. For small bars and rods, an ultimate resistance between 75 000 and 85 000 ; elongation not less than 20 per cent. in 8 inches ; limit of elasticity above 40 000 pounds per square inch. For large flat bars, an ultimate resistance between 70 000 and 80 000 ; elongation not less than 15 per cent. in 8 inches ; limit of elasticity above 38 000 pounds per square inch. In addition, the steel must be satisfactory as to its hardening tendency, bending tests, etc., with such other practical conditions as may ensure a certain and reliable material for the required purpose.

In this connection it will be well to draw attention to one or two points which are frequently overlooked :

1st. The importance of a more accurate measure of the tensile elongation in reference to the rapidity of the applied strain. It is well known that the tensile strength and elongation can be made to vary by applying the strain more or less rapidly ; and partly due to this cause different machines or different operators of the same machine may obtain different results upon the same material.

2d. The necessity of determining the ductility of the metal at different temperatures. Certain mild steels, which can be bent cold or hot, break readily by percussive action at a medium temperature (600°).

3d. The desirability of testing all steel by impact or a falling weight. It has been found that certain steels, showing the same results under a tensile test, give varying resistances to impact, which would seem to show the effect also of a variation in the rapidity of the applied strain. At a slow velocity of strain the two metals may flow alike, but at a higher velocity their results are different.

What is the increase in the working strain that can be adopted for this class of steel over that used for the same members in iron ?

Bearing in mind that the above tensile requirements apply to specimens, and that upon long pieces such as would be used in practice, both the ultimate and elastic stresses would be considerably lower ; and that the reduced weight of the structure would increase the effects of impacts and vibrations of rapidly moving trains, or from derailment of part of a train ; we would not deem it advisable to increase our customary working strains used for iron bridges more than 50 per cent.

What kind of steel, in reference to the make, will be most suitable for bridges ? This question must be decided by the relative cost of such material as will fill the requirement.

The three processes of making steel, Crucible, Bessemer and Open Hearth can all undoubtedly fill these requirements ; their relative cost must, therefore, decide the question. This relative cost does not consist solely upon what it may cost each process to make a ton of steel (in general), but what it will cost them to make a specified amount of a particular steel, and to get rid of such ingots as will not suit the purpose. This will largely bring the question down to the comparative certainty by any one process or establishment of obtaining the exact steel required with the least waste or surplus of unprofitable material.

The additional cost of smelting would apparently rule out the crucible steel. For the other processes it would be reduced to a competition between establishments.

What effect will the substitution of steel for iron have upon the proportions for economy, and upon the form of the several members and their detail parts ? That there will be a change in proportions best suited for economy is very probable, but it can only be solved by practical competition between different designs, as it has been in iron ; it

appears likely, that relatively lower heights of spans will be adopted for moderate sized spans, at least—owing to the necessity of avoiding too thin sections of metal.

As to the latter portion of the above question, the form of members and their details, undoubtedly, a change will be required. The best form of eye and proper size of pin-hole in eye-bars, the best and most economical method of riveting together the parts of members, the best form of compression members, etc., can only be definitely determined by future experiments. Experience already obtained upon steel teaches us the necessity of avoiding all local strains; not only those due to mechanical work but also those due to local attachments. Greater care must, therefore, be taken to transfer a stress uniformly over the whole section of a member. This would point towards the use of a greater number of small rivets instead of a few large ones for making local attachments to the webs of plate girders, sides of posts and chords, &c.

Sharp re-entrant angles must be avoided by the introduction of a large fillet.

Time, with its increasing experience and the ingenuity of designers, will, undoubtedly, develop new and proper forms for the several parts so as to avoid all objectionable features and expensive processes.

It is to be hoped that we are to receive from the Chief Engineer of the Glasgow Bridge a report of the experiments made and experience gained during its construction. A full account of the condition of all parts of the wreck of the fallen span would give us much information. It would be very desirable to have the doubtfulness of steel, under certain conditions, disproved if possible.

To what extent can steel be economically substituted for iron in different sized structures and in different parts of the structure?

The proportionally great effect of oxydation upon very thin or small sized members, and their small resistance to accidental blows, has shown the necessity of limiting, in iron, the thickness of sheets to a minimum of about one-fourth of an inch, and the diameter of the smallest rod to about one inch. Similar reasons would justify the adoption of the same sizes in steel.

The practical difficulties of the rolling process will also establish limiting thickness for channels, angles, beams and other shapes, in steel as it has in iron. And it is not probable that these shapes in steel can be rolled very much, if any, thinner than in iron, and certainly not

thinner in proportion to the relative strength of the two materials. In any sections, therefore, which approximate to these minimum sizes, there will be no gain in the use of steel, unless its price is near that of iron.

Upon the supposition that the cost of steel is proportionally equal or less than the cost of iron, considering their relative working strains, steel could be substituted for the tension members of the trusses in all but exceedingly small spans.

In the lateral system, steel rods could only be used in bridges over 150 feet.

Whether the pins in any sized span should be changed to steel, would depend largely upon the methods of transferring the strains to and from the other members, it being questionable whether large iron pins would not answer this purpose better than smaller steel ones.

In compression members, as we must retain relatively the same diameters as in iron, if we are to increase the strain proportionally to the strength of steel over iron, we cannot reduce the weight of lateral struts in spans below 150 feet. Neither can we reduce much the weight of the intermediate posts and lighter top-chord sections in spans below 150 feet.

The use of rolled beams will be limited by the fact that they deflect under equal strains nearly the same as iron and cannot be rolled much thinner.

The reduction in built beams will depend, likewise, upon the span and the limited sizes of the parts. The thickness of the web plates cannot be proportionally reduced, as their thickness will be dependent upon their power to resist buckling.

From such detailed considerations it is evident that there will be no economy in the use of all steel in spans of ordinary sizes (single track bridges up to 150 or 175 feet) as long as steel is dearer than iron. At what exact points the use of all steel will be the most economical, can only be determined by comparative estimates upon particular plans. When the length of spans becomes greater, an appreciable saving in weight to be carried increases the economy. In spans from 200 to 300 feet long, this will amount to a saving of about 5 to 12 per cent.

Relative cost of manufacturing steel and iron bridges.—This can only be answered by a more extended experience than we now possess, and in the future will largely depend upon the development of new plant and new methods of manipulation. But for the present, considering the ad-

ditional care required in all the processes and the necessity of substituting temporarily processes which are more costly than those heretofore used in iron structures, the cost of manufacturing steel structures must be higher than for iron ones.

As a believer in the great adaptability of steel for mechanical and structural purposes, only limited by its relative cost and a proper knowledge of the manner of working and using it, the writer has endeavored to draw attention to such facts as would seem to govern the successful introduction of the use of steel.

As the first successful iron bridge builders were those who were able to throw aside the traditions and practice of the users of wood and adapt their designs and processes to the capabilities of the metal, iron—so must the successful builders in steel be those who can accept the fact that the new metal, structural steel, requires a like sacrifice of old traditions and practices, a development of new plant and processes, and the education of a new class of metal workers.

DISCUSSION

On the Paper, "The Use of Steel for Bridges," at the Meeting of the Society, September 17th, 1879.

By T. C. Clarke, Charles Macdonald, O. Chanute, D. Torrey and Theodore Cooper.

T. C. Clarke.—The Society is much indebted to Mr. Cooper for his exceedingly thoughtful and suggestive paper on the use of steel, which has covered the ground so completely that there is not much left for any one else to say.

I would, however, remark, that I have just received from C. O. Gleim (Member Am. Soc. C. E,), Engineer of the Central Bureau of Rhenish Railways, Cologne, a very interesting letter, from which I quote the following statement as to the abandonment of steel in Holland for riveted girders:

"I do not know whether you have heard of the recent experience of Dutch engineers in regard to the use of steel in bridge building, which has led to its entire abandonment in Holland. It is a well known fact that the Kuilenberg bridge has its floor system constructed of steel; and since its erection, the same system has been adopted for most of the large

iron bridges built in Holland. The only bridge that I have heard of with the main girders constructed of steel, is a plate-girder bridge, carrying a number of railroad tracks of the Amsterdam Central Station across a canal; and it was on this bridge that their steel girders first came to grief. After making a series of experiments, they concluded to give up the use of steel altogether on their government bridges. There were two large bridges, across the Rhine at Arnhem, and across the Waal at Nymegen, in course of erection at the time; and a Dutch engineer wrote to me last summer, that, on the strength of those experiments, the steel floor-beams and track-stringers of the Arnhem bridge were taken out again; and that in the case of the Nymegen bridge, where it was too late to exchange them for iron beams, although the bridge was not opened for traffic, they resorted to the rather doubtful remedy of strengthening them by the addition of new chord-plates. I have unfortunately mislaid the data I have from another engineer in regard to the experiments referred to. But the main fact was, that they built up riveted beams, of their floor-beam section, out of plates and angles that had previously been subjected to severe tests of their tensile strength; and that on loading these beams transversely, they were found to give way under a computed strain only a fraction (down to one-third, I think,) of what they had previously borne. One of the angles would suddenly snap, while the rest of the section continued to bear the transverse strain."

This illustrates clearly the necessity pointed out by Mr. Cooper, of so treating the steel as not to injure it in manufacture. No maker of steel has yet been able to overcome the danger of steel suddenly giving way when nicked or cut into. These Dutch girders were probably injured in punching or drilling, or in riveting.

I would say that, taking into account our ignorance of the ultimate strength of a framed structure, as a whole, as distinguished from the strength of its parts, I would not be willing, in the present state of our knowledge to strain steel bridges even fifty per centum more than iron, which was the maximum recommended by Mr. Cooper.

C. Macdonald.—I have seen some of the steel eye bars that were used in the Glasgow bridge during their construction at the works of Andrew Kloman, Esq., Pittsburgh. They appeared much smoother and more regular than the best wrought iron eye bars ; and from the method employed by Mr. Kloman in forming the eye, the difficulties attending the upsetting or die forging operations seem to be eliminated.

I have also seen photographs of the eye bars that had been taken out of the wreck of the Glasgow span, which was carried away by the ice during the process of erection; they were bent and twisted in every conceivable direction. Nevertheless, they were sent back to the shop,

reheated and straightened, and put back into the bridge. General Sooy Smith, Member of the Society, engineer of the bridge, informs me that only four eye bars were broken in the fall, although they were not so fortunate with the compression members.

When it is remembered that in this accident upwards of 250 tons of finished steel were precipitated from a height of 80 feet into the river, with so little injury to the material, it at least furnishes some evidence of the possibilities of steel as a material for bridge construction.

Referring to the question of ductility, it would be well, perhaps, to consider whether it is necessary that, in general, a low grade of steel should be selected for structural purposes, in order to insure a high degree of ductility.

I find that many makers of steel, who are themselves scientific observers, do not hesitate to use high steels to resist shock and vibrations. Mr. William Metcalf, Member of the Society, an eminent steel manufacturer of Pittsburgh, informs me that he finds cast steel, having as high as $\frac{9}{10}$ carbon, gives the best results in the vibrating parts of agricultural machinery; and at his own works he has used a similar grade of steel for steam-hammer rods, where the shocks are certainly of the most violent character; yet they have outlasted those made from more ductile material.

From Kirkaldy's experiments on the Fagersta steels, it would appear that at $\frac{9}{10}$ carbon a maximum tensile resistance is reached, giving an average of 63 000 elastic stress and 106 000 ultimate; while the ductility, as measured by the contraction of area at fracture was only $\frac{1}{10}$ as great as in the specimen having $\frac{3}{10}$ carbon.

In such portions of a bridge as, for instance, the bottom chords, where great accuracy of workmanship may be relied upon, with our present appliances, would it not be well to take advantage of this superior tenacity of the high steels, by using them at a strain approaching 20 000 per square inch, rather than the figure mentioned in the paper?

For compression members we are not so sure of the results of the operations in the shop, such as punching, riveting, &c. Hence it would be more prudent to utilize the lower grades until further information is obtained.

O. Chanute.—It is not improbable that some of those who look upon steel as the coming material for bridges shall find themselves rather disappointed at the results arrived at in Mr. Cooper's paper, in

this, that they do not indicate more definitely the economy and advantages which may be expected to result in bridge construction from the substitution of steel for iron.

Such a first impression would, however, be erroneous. It can scarcely be expected that at the very threshold of the introduction of steel, and in the absence of definite information concerning the adaptability and homogeneity of the material, we can reach any very positive conclusions.

Mr. Cooper's paper is, from the very nature of things, in the character of a preliminary inquiry, and the thanks of the Society are due him for furnishing this first nucleus, around which other contributions may crystallize. It now remains for the individual members to endeavor to agree upon specifications for the use of steel in bridges, and to point out what further experiments are needed in order to gain an adequate knowledge of the capacities of this metal.

I quite agree with the author, that the engineer who proposes to use steel should chiefly concern himself with the physical characteristics of the product, and should not attempt to specify to the manufacturer either its chemical constituents or its manipulation. For a while, however, until we know more about it, it is probable that the chemist, the manufacturer, and the testing engineer will have to proceed simultaneously hand in hand, until the composition of the metal, its manufacture, and its capacities are thoroughly understood, and the uniformity of its production assured.

I also quite agree with the author, that the rate of speed with which strains are applied has much to do with the behavior of the specimen. Many hundreds of experiments have convinced me of this, and I would recommend that some basis be agreed upon as to the speed with which specimens of various sizes are to be tested.

As to the size of test pieces, I herewith submit a print, Plate XLIX, of the dimensions which we have adopted in our practice upon the Erie Railway. We have obtained the most satisfactory results from the long specimens.

The general attitude of engineers on the subject of bridge steel may be stated as one of expectancy. It is only of late years that it has been produced cheaply enough to warrant us in thinking of employing it at all; and while most of us believe it to be the material of the future, we are still inclined to put the burden of proof upon the steel makers, and to require them to furnish evidence of its adaptability and economy before we will agree to use it.

N.Y.L.E.&W.R.R.

Sample Bars of Wrought Iron for Tests of Tensile Strength

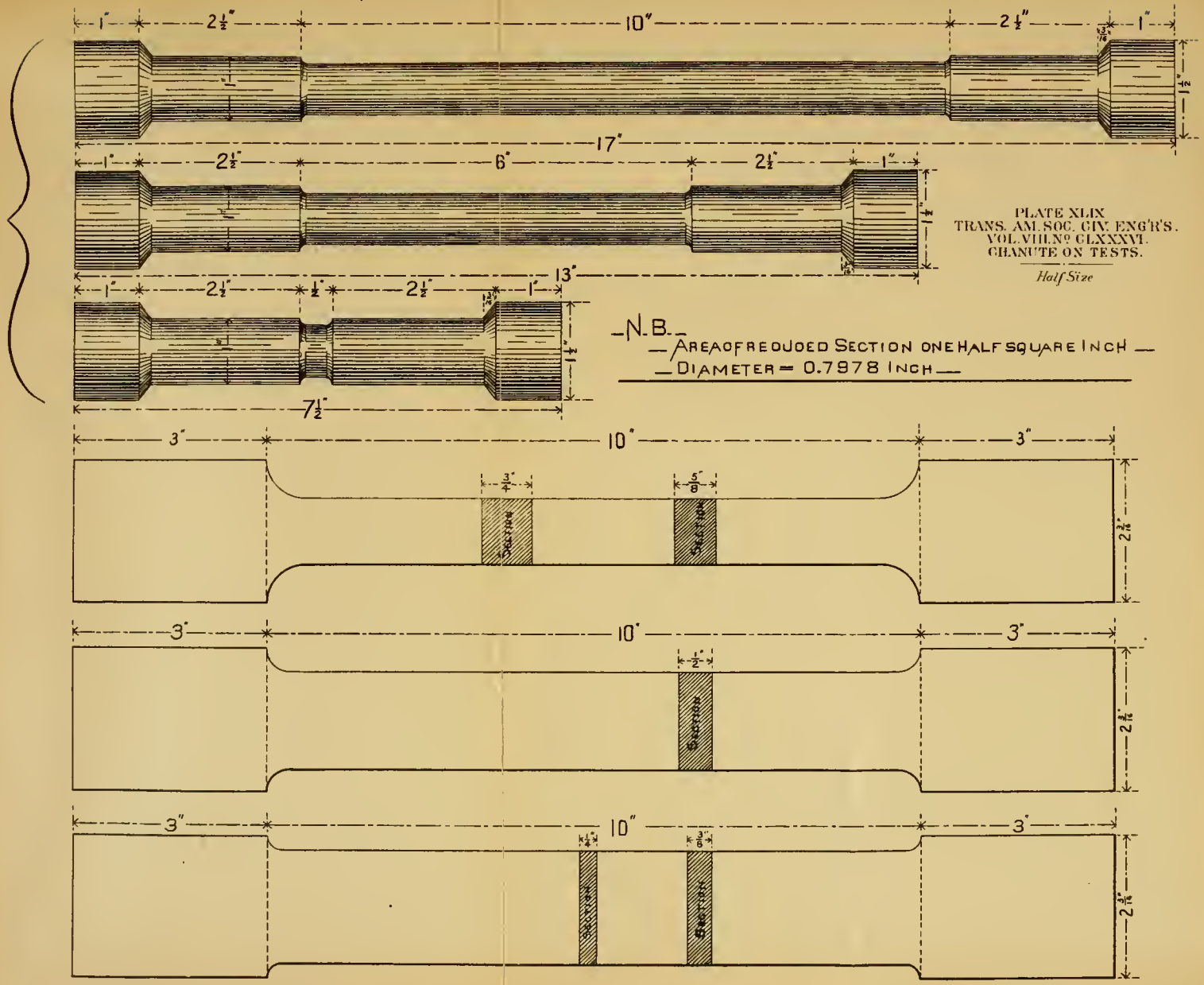

PLATE XLIX
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. VIII. Nº CLXXXVI.
CHANUTE ON TESTS.

Half Size

N.B.
Area of reduced section one half square inch
Diameter = 0.7978 inch

The bridge specification of the New York, Lake Erie & Western Railroad says in reference to steel :

"Sec. 14.—The following clauses are intended to apply to iron construction. Parties proposing to substitute steel for particular parts will be required to furnish evidence of its strength, elasticity, uniformity in production, and adaptability to the intended purpose."

The propriety of these requirements will be apparent, if we consider them in detail.

As to ultimate strength, we know that in tension steel ranges all the way from 50 000 to 300 000 pounds to the square inch which latter strength it has reached in the shape of fine wire. That in compression it begins to yield, or rather to be distorted, at from 40 000 to 90 000 pounds per square inch, while no one knows what its ultimate crushing point is for sections several inches in area, nor what weight will squeeze out flat even a single cubic inch of steel.

In fact, the great range in the strength of steel is one of the principal obstacles to its use. We do not know how much we can expect from it nor what strain it is safe to impose, and as prudence dictates that we shall assume the strength to be that of the weakest piece, we cannot, at present prices, generally use this metal in bridges with any marked economy until we know more about it.

There are a number of patent processes, more or less well known, of making steel by the addition of various metalloids, which are said to give uniform and satisfactory results. We know much less about them than is essential to their general employment, and hitherto the cost price has been so great as to prohibit the use of the metal in any but very large spans.

The author has judiciously insisted in his paper upon the importance of ductility in steel, and it may be pointed out in passing that much of the success of American iron bridge building has been due to our employment of soft, elastic metal, especially in all tension members. Although we take the utmost pains to secure accuracy of finish of the several parts—planing or turning all joints and bearings, boring all eye bars at the same temperature to fit the pins within one-fiftieth of an inch, and rejecting them if, when all the bars of one system are piled on top of each other, the pins do not pass through at both ends simultaneously without driving ; although, in fact, we treat and finish our bridges as tools or machines, while in other countries they are treated as structures,

with the inaccuracies and defects inherent to that mode of construction, yet it may occur that when several members are placed side by side in a bridge, some of them will at first take a little (perhaps very little) more of the strains due to their position than others. Here the elasticity of the material comes into play. The bars which are first loaded yield a little and transfer part of their strains upon the others, until they are fairly equalized, and all substantially carry the same ratio of the load.

One difficulty is here likely to occur with steel. It is understood that its modulus of elasticity varies greatly, say from 25 000 000 to 35 000 000 of pounds, or a range of forty per cent., so that if bars with different moduli are placed side by side, it is not certain that the strains will be equalized among them as perfectly as now occurs with iron.

It is, however, in respect to the uniformity of production, the homogeneity of the material, that the greatest difficulties are to be surmounted. It seems to be understood that high carbon steel, made at the same works from the same materials, differs materially day by day in its strength and elasticity, and as we cannot well test a sample out of every bar, we cannot now be sure of just what strength we shall have in a bridge when we place the various bars side by side. It is true, that in boiler steel practical uniformity has been secured, and the product is homogeneous, but this contains only from $\frac{6}{100}$ to $\frac{10}{100}$ of one per cent. of carbon, and is substantially weldless iron of soft quality, while it costs five or six cents a pound, or enough to prohibit its use in bridges.

I have here tables of experiments (pages 284 and 285,) recently made upon boiler steel and iron for the New York, Lake Erie & Western Railroad, from which it appears that while the steel plates showed an ultimate strength, varying from 50 950 to 62 310 pounds per square inch, with a general average of about 52 000 pounds, and an elastic limit of 29 340 to 42 350 per square inch; the "Ulster iron" from which the stay bolts were made showed an ultimate strength of 48 000 to 52 000 pounds and the elastic limit of 28 000 to 33 000 ponnds per square inch, or from five per cent. to ten per cent. less than the steel.

I think in this matter we shall have to call upon the manufacturers to co-operate with the Society, by sending to the Committee on Tests numerous samples of their products of steel to be tested in small specimens by a uniform method, and to have the results published from time to time. Perhaps the interest thus awakened may induce Congress to

make a fresh appropriation for the testing of American iron and steel, so that we may have tests made upon full sized members, and thus acquire knowledge which we sorely need, before we can commit ourselves fully to the employment of this material.

The figures below give the dimensions of the specimens tested, and referred to in the following tables.

Fortunately, the use of steel will accord very well with the characteristics of American iron bridge practice, as it has been developed during the past fifteen years, creating a type differing materially from those of other countries, which has not inaptly been called the "skeleton type."

These characteristics differ from those of European bridges chiefly in the following particulars :

1st. The great depth which we give to our trusses in proportion to their length, endeavoring always to obtain the most economical depth for each span. Thus, the height of our bridges is generally from one-fifth to one-seventh of the span, while that of European bridges is from one-eighth to one-twelfth.

2d. The designing of bridges so that the direction taken by the strains and their distribution shall be absolutely certain, in order that the effect can be accurately calculated. There is no ambiguity or doubt as to the way strains are distributed in skeleton structures, while in plate

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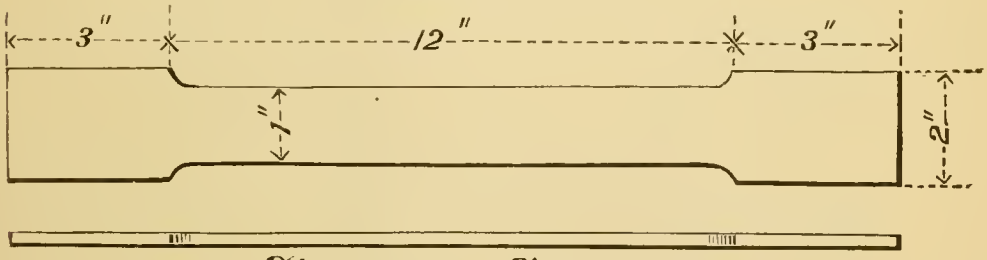
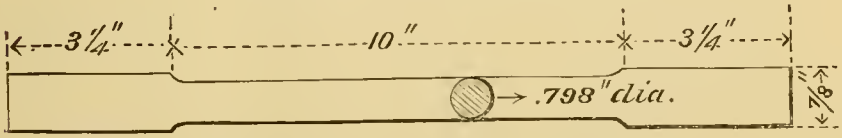
Steel Boiler Plate.



Standard Specimen

One-fifth full size.

Stay Bolt (Ulster Iron).



Standard Specimen

One-fifth full size.

Tests of Tensile Strength of Material used in construction of Boilers for Consolidation Engines built by the Grant Locomotive Works, Paterson, N.J.

No. of Specimen and Mark.	Original Section.	Fractured Section.	Ultimate Strength per Square Inch. Original Section	Ultimate Strength per Square Inch. Fractured Section.	Elastic Limit per Square Inch.	Percentage of Elongation	Percentage of Red'n of Sect'n	Remarks.
			Steel Boiler Plate.					
	Inches.	Inches.	lbs.	lbs.	lbs.			
1 608	1.026 × .325 .333 □	.725 × .214 .155 □	50 982	109 571	29 990	$21\frac{5}{12}$	$53\frac{12}{25}$	
1 609	1.020 × .317 .323 □	.741 × .220 .163 □	52 576	104 281	33 401	22.3	$49\frac{3}{5}$	
1 610	1.015 × .390 .396 □	.791 × .258 .204 □	57 597	111 721	35 998	$16\frac{1}{8}$	$48\frac{4}{9}$	Laminated.
1 611	1.010 × .390 .394 □	.750 × .256 .192 □	59 406	121 875	38 715	$20\frac{4}{5}$	$51\frac{1}{4}$	
1 612	1.020 × .498 .508 □	.926 × .422 .391 □	59 256	77 027	37 896	$12\frac{15}{16}$	$23\frac{1}{4}$	Laminated.
1 613	1.017 × .503 .511 □	.859 × .390 .335 □	60 795	92 833	37 142	$12\frac{17}{25}$	$34\frac{1}{2}$	Laminated.
1 614	1.025 × .508 .521 □	.730 × .344 .251 □	51 853	107 518	30 728	$24\frac{1}{4}$	$51\frac{7}{9}$	
1 615	1.021 × .450 .459 □	.690 × .270 .186 □	51 692	127 482	29 340	$24\frac{1}{25}$	$59\frac{9}{20}$	1608 to 1615 incl. Tested Sept., 1878.
1 677 T 1	1.015 × .335 .340 □	.869 × .218 .189 □	52 941	95 017	30 882	$20\frac{5}{12}$	44.28	
1 678 T 3	1.009 × .325 .328 □	.820 × .188 .154 □	51 080	108 653	32 020	$14\frac{1}{6}$	52.98	
1 679 B 5	1.004 × .325 .326 □	.758 × .205 .155 □	56 696	119 050	32 945	$15\frac{5}{6}$	$52\frac{1}{3}$	
1 680 B 6	1.005 × .332 .3336 □	.806 × .175 .141 □	50 950	120 524	30 720	$20\frac{1}{6}$	57.72	
1 681 B 7	1.0 × .323 .323 □	.764 × .205 .1566 □	57 890	119 400	33 280	$17\frac{1}{12}$	$51\frac{1}{2}$	
1 682 L 2	1.0 × .325 .325 □	.767 × .208 .159	54 615	112 260	33 077	$21\frac{1}{12}$	50.9	
1 683 L 4	.998 × .328 .327 □	.786 × .183 .144 □	53 460	121 660	32 840	$20\frac{2}{3}$	56.06	
1 684 T 2	.996 × .338 .336 □	.822 × .284 .233 □	55 690	80 317	37 870	$9\frac{1}{6}$	30.65	
1 685 L 6	1.0 × .334 .334 □	.770 × .183 .141 □	52 395	124 190	33 680	$20\frac{11}{12}$	57 81	
1 686 R 17	1.003 × .33 .33099 □	.76 × .175 .133 □	52 116	129 700	36 255	$16\frac{1}{4}$	59.81	
1 687 R 8	1.002 × 323 .3236 □	.777 × .178 .138 □	56 388	131 950	41 600	$16\frac{7}{12}$	57.26	
1 688 R 11	1.00 × .339 .339 □	.775 × .184 .1426	55 310	131 480	39 823	$14\frac{1}{6}$	57.93	1677 to 1688 incl. Tested Jan., 1879.
			Ulster Iron for Stay Bolts.					
1 644	dia. .798 0.5 □	dia. .580 0.2641 □	50 000	94 620	33 000	26.7	47.16	Indications of slag in these four (4) samples.
1 645	dia. .798 0.5 □	dia. .633 0.3147 □	49 000	77 850	32 000	21	37.06	
1 646	dia. .798 0.5 □	dia. .630 0.3117 □	49 900	78 560	28 500	22	37.65	Samples for 1st 10 engines, 1644 to 1647 inclusive.
1 647	dia. .798 0.5 □	dia. .575 0.2596 □	49 500	95 310	31 000	26	48.06	Tested Nov., 1878.
1 660	dia. .798 0.5 □	dia. .619 .301 □	48 500	80 583	28 000	20.6	39.81	Indications of slag in these four (4) samples.
1 661	dia. .798 0.5 □	dia. .588 .2715 □	48 500	89 302	30 500	$26\frac{4}{5}$	45.69	
1 662	dia .798 0.5 □	dia .625 .307 □	48 000	78 227	28 000	24	38.64	Samples for 2d 10 engines, 1660 to 1663 inclusive.
1 663	dia. .798 0.5 □	dia .612 .294 □	50 600	86 005	32 000	$22\frac{1}{2}$	41.17	Tested Dec., 1878.
1 673	dia. .798 0.5 □	dia. .591 .274 □	48 400	88 215	27 500	24	45.13	Indications of slag in these four (4) samples.
1 674	dia. .798 0.5 □	dia. .567 .252 □	52 000	102 970	30 500	24	$49\frac{1}{2}$	
1 675	dia. .798 0.5 □	dia. .582 0.266 □	49 000	92 095	29 500	24.5	46.79	Samples for 3d 10 engines, 1673 to 1676 inclusive.
1 676	dia. .798 0.5 □	dia. .588 0.271 □	48 000	89 302	29 000	21.6	45.69	Tested Feb., 1879.

Tested at Stevens Institute of Technology.

Boiler Plate Steel for N. Y. L. E. and W. R. R.

No. of Specimen.	Material.	Original Section.	Fractured Section.	Ultimate strength per sq. inch.		Elastic Limit per sq. inch.	Percentage of		Original and Final Length.	Remarks.
				Original Section.	Fractured Section.		Elongation.	Reduction of Section.		
		Inches	Inches.	lbs.	lbs.	lbs.			Inches.	
1742	Boiler plate steel.....	1.011 × .314	.646 × .191						10	
		.317□	.123□	56 700	145 900	38 590	15.1	61.13	11.51	Marked, "Steel Boiler Plate."
1743	Boiler plate steel	1.013 × .319	.633 × .207						10	
		.323□	.131□	56 480	139 280	38 680	13.3	59.45	11.33	" " "
1744	Boiler plate steel	1.011 × .427	.675 × .26						10	
		.432□	.175□	57 330	141 030	35 330	17.7	59.35	11.77	" " "
1745	Boiler plate steel	1.006 × .428	.684 × .253						10	
		.430□	.173□	56 900	141 580	35 420	18.5	59.81	11.85	" " "
1746	Boiler plate steel	1.013 × .507	.72 × .331						10	
		.513□	.238□	60 360	130 080	36 510	15.6	55.6	11.56	" " "
1747	Boiler plate steel	1.011 × .508	.779 × .363						10	
		.514□	.283□	62 310	113 160	42 350	13.0	44.94	11.3	" " "
										Tested May 6th, 1879.

Tested at Stevens Institute of Technology.

girders and lattice bridges considerable material has to be added to allow for the possible imperfections of the riveting, and to prevent buckling.

3d. The concentration of the material into as few parts as possible, thus gaining the double advantage of reducing the number of connections (which merely transfer the strains from one member to another) to a minimum, and, consequently, saving both material and labor, and of generally making each member so large that it protects itself against weakening by oxydation and against accidental blows.

4th. As a consequence of the last two features, the general use of pins for connections. Even, however, when we use riveted connections, we preserve the great depth of truss, the skeleton design, and the concentration into few members by using large panels and making the compression members of *T* sections, thus building "trellis bridges" instead of the "lattice" bridges made of small, flat bars requiring vertical stiffness, such as have been so extensively used in Germany.

5th. The adoption of light, open floors of iron or wood, providing the necessary elasticity by wooden ties, and providing against danger from derailments by placing these ties about 6 or 8 inches apart in the clear, and surmounting them with a heavy guard beam, so that derailed wheels may run across the floor without either dropping through or "slewing" around, so as to allow the cars they carry to strike the sides of the bridge. These are equally safe, and far cheaper than the heavy ballasted floors, so common in European bridges, which are thought there of advantage in counterweighting the girder against partial loads, the necessity for this being obviated by our peculiar mode of construction.

These features have enabled us to perfect, in spite of some early failures, a general style of iron bridges, which is now admitted to be thoroughly efficient and safe when designed by competent builders, and which weighs from 10 to 25 per cent. less, for equal loads and strength, than the bridges built upon standard European types.

Now, in view of these features, what requirements and strains are we likely to adopt for steel bridges? We are all agreed upon the modes of calculating strains, and pretty well agreed as to specifications for iron bridges. Can we now agree upon a steel specification?

The author of the paper under discussion states in general terms that it would not be advisable to increase our customary working strains used for iron bridges more than 50 per cent., and I quite agree with him.

We now allow upon iron the following strains in tension :

	Pounds. per Square In.
On lateral bracing	15 000
" solid rolled beams, used as cross floor beams and stringers	10 000
" bottom chords and main diagonals	10 000
" counter rods and long verticals	8 000
" bottom flange of riveted cross-girders, net section	8 000
" bottom flange of riveted longitudinal plate girders *over* 20 feet long, net section	8 000
" bottom flange of riveted longitudinal plate girders *under* 20 feet long, net section	7 000
" floor beam hangers, and other similar members liable to sudden loading	6 000

This is upon metal which by the specification may range from 48 000 to 50 000 pounds per square inch for plates, angles, and channels, with an elongation of 15 per cent., from 50 000 to 52 000 pounds per square inch for small bars and rods, with an elongation of 18 per cent., and from 46 000 to 50 000 pounds per square inch, with an elongation of 15 per cent. for large flat bars.

We may say, therefore, that with the exception of floor beam hangers, and other similar parts exposed to great fatigue and impact with every passing load, we utilize in tension 20 per cent. of the ultimate strength of the iron ; or if we calculate it, as I believe to be more correct, upon the elastic limit of the iron, which is, generally, from 24 000 to 26 000 pounds to the square inch, that we utilize 40 per cent. of the strength beyond which it takes a permanent set.

If we should observe the same proportions for steel, we could place upon plates, angles, and channels (which the author proposes shall be of metal with an ultimate strength of 65 000 to 70 000 pounds per square inch), strains varying from 13 000 to 14 000 pounds per square inch ; upon small bars and rods, with an ultimate strength of 75 000 to 80 000 pounds per square inch, strains of 15 000 to 17 000 pounds per square inch ; and upon large, flat steel bars, with a strength of 70 000 to 80 000 pounds per square inch, strains of 14 000 to 16 000 pounds per square inch.

Or if we base our strains upon the elastic limit, which the author proposes shall be 35 000 to 40 000 pounds, we could, by utilizing 40 per cent. of this, strain the steel from 14 000 to 16 000 pounds per square inch.

This agrees pretty closely with the result arrived at by adding 50 per cent. to the strain allowed on iron in tension, as previously stated, giving, (if we omit the floor beam hangers, the bottom flange of riveted plate girders under 20 feet long, and the lateral bracing,) strains allowable for steel, of 12 000 to 15 000 pounds per square inch.

An incidental advantage, however, is likely to result in some parts of bridges, from the use of steel in tension, by the opportunity which the greater strains allowed will afford for reducing the number of parallel parts of members dividing the duty between them, and thus making our bridges more compact, as well as insuring a more accurate distribution of the loads among the fewer pieces which are expected to pull together.

With respect to compression members, we are woefully ignorant of their real strength in full-sized members, mainly because until quite recently there has been no reliable machine strong enough in this country to cripple top chord pieces and large struts. The Government machine, which is just done, could give us almost invaluable information on this subject, but unfortunately the want of an appropriation has locked it up beyond reach.

There is reason to suspect that in our ignorance of the real crippling or distortion point of large compression members, and of the best form to be given to them, we are now underloading them, and wasting considerable quantities of material.

4.—In beams and girders compression is limited, as follows :

	Pounds per Square In.
In rolled beams, used in cross floor beams and stringers.....	10 000
" riveted plate girders, used as cross floor beams, gross section...	6 000
" " longitudinal plate girders *over* 20 feet long, gross section.	6 000
" " " " " *under* 20 ft. long, gross section.	5 000

In top chords, posts, and struts, the strains are calculated by a modification of Rankine's formula, as follows :

$$P = \frac{8\,000}{1 + \frac{L^2}{40\,000\,R^2}}$$ for square end compression members.

$$P = \frac{8\,000}{1 + \frac{L^2}{30\,000\,R^2}}$$ for compression members with one pin and one square end.

$$P = \frac{8\,000}{1 + \frac{L^2}{20\,000\,R^2}}$$ for compression members with pin bearings.

P = the allowed compression per square inch of cross section.
L = the length of compression member, in inches.
R = the least radius of gyration of the section, in inches.

The lateral struts are proportioned by the above formulæ, to resist the resultant due to an assumed initial strain of 10 000 pounds per square inch upon all the rods attaching to them, produced by adjusting the bridge.

This gives from 8 000 to 4 000 pounds per square inch of allowed compression upon square ended members, as usually proportioned.

Now, it must be remembered that this is based upon the *crippling point* of small members only, such as we can test in ordinary machines, and that not only are we not sure that large members will behave quite in the same way (in fact we know that both in stone and iron, cubes of, say 4 inches, are more than 16 times as strong in compression, than cubes of 1 inch); but to be on the side of safety, we utilize but 20 per cent. of the assumed crippling strength, which really corresponds to the elastic limit in tension, of which we utilize 40 per cent.

When we come to use steel it may be wise to consider whether it wil not be safe to increase materially the compressive strains which we shall allow.

If the formula quoted above is correct for American iron it gives a crippling point varying from 40 000 pounds for 1 diameter to 23 000 pounds per square inch for 70 diameters, and we may, perhaps, find it safe to utilize in steel, something more nearly approximating 40 per cent. of the strains at which distortion begins,

The final test by which the use of steel shall be determined must, of course, be its economy over iron. If we assume, in a general way, that it will cost no more for manipulation in the shop, for transportation and for erection than iron, we may ascertain approximately the price at which a reliable uniform product must be sold in order to enable it to compete.

The base price of bridge iron is now about 2½ cents per pound, and if it is determined that it can be strained on an average 50 per cent. more than iron, it must be sold at 3¾ cents a pound to make its economy equal. It is for the manufacturers to say whether they can give us a reliable, ductile and safe steel at this price.

We cannot too strongly insist, however, upon the importance of homogeneity and uniformity in production. We must have a material

upon which we can rely as generally as we now do on iron, and we must understand its peculiarities and behaviour under manipulation thoroughly.

To obtain this knowledge there seems to be no way open but careful experiment, first in the testing room, and then in actual construction. It may possibly be that after all, steel shall not prove more economical than iron for bridge construction, but the chances of its becoming so will certainly warrant the trial.

For long spans, say those over 350 feet, where the dead weight of the bridge is greater than the moving load, it is probable that steel is already cheaper than iron for the main members, because it saves in its own weight, to the extent of the greater strains, which it will be found safe to impose upon it.

Such great spans, however, are rare, and it should be the endeavor of those who may be interested in bringing steel into use, so to develop its capacities, establish its safety, ensure its uniformity of production and cheapen its cost, as to enable us to make new specifications which will insure its substitution for iron in spans of, say 100 to 200 feet, such as are in daily demand.

D. Torrey.—What I have to say relates more to metallurgy than to engineering, and while really in the same line of study and research as the greater part of the papers before us, is yet so pertinent to the problem of steel bridges as to be acceptable, I trust, to you.

In giving my opinions, it should be clearly understood that they are offered as conclusions based upon experience not specially related to bridge building, as may be the case with others who share in the discussion. In a word, we are looking forward, not summing up. It is safe to assume that the one great difficulty preventing the general adoption of steel as a bridge building material, is the wide-spread belief that the metal is, to use a common expression, treacherous. The frequency with which pieces of steel, purchased with a guarantee of high tensile strength and superior quality, have unexpectedly broken, either while being manufactured or while in service, and this in positions that iron has filled much better, has carried conviction to the minds of many engineers that its use in bridge construction involved too much risk. This conviction has been strengthened by the absence generally of any fair explanation of the cause of failure, or the honest confession given by saying, "I don't understand it." Laboratory tests, which show how very much superior steel

is to iron, are of no value in seeking a solution of the problem; and the greater the degree of confidence with which a man tries steel as a substitute for iron, the more emphatically does he reject it when it fails to serve his purposes so inexplicably as it sometimes does.

What is most wanted is some way to make steel safe for structural purposes, without also making it too costly. Why is it unsafe? Probably because it is not handled with sufficient care in the process of manufacture, and during subsequent manipulation and transportation; and what I have to suggest is the preparation of steel in a condition to be much less sensitive than it usually is to these adverse influences.

Many persons do not know how difficult it is to secure uniformity in quality with any considerable number of pieces of steel. Blooms from the same ingot, when reheated, vary in carbon according to their positions in the heating furnace, as also the length of time they lie in it; and they vary in physical characteristics according to the manipulation they receive—variations depending upon temperature when taken to the rolls, speed of rolling and conditions of cooling, etc.

The surface defects of a piece of steel, such as hammer marks, cracks, etc., even when invisible to the eye, may cause it to break if the piece is subject to vibratory strains, when a like piece of iron would not fail. The milder the steel the less the cohesion between its particles, and the less tensile strength, and while this ready adjustment of its molecules under stress fits it for bridge and other structures, its low tensile strength gives it little advantage over iron. High tensile strength steel will probably resist the appearance of incipient fracture better than low tensile strength steel, but when the incipient fracture is present the high steel will be much the weaker. High steel, when mechanically perfect, that is to say, without surface cracks, however fine, and without internal flaws or external hammer marks, will, from its greater molecular cohesion, resist vibratory strains better than low steel.

This has been illustrated in the experience of Mr. William Metcalf with the piston rod of a steam hammer, who reports that while wrought iron endured three months, mild steel six months, high steel, 60 carbon, endured two years. These pistons were too large to crush and were not subject to flexure; they were always broken.

By ordinary processes of manufacture mild steel has porous cavities in the ingots. Some authorities say it is never without them, and as it will not bear heating to a temperature high enough to enable us to weld

the walls of these cavities in the subsequent process of rolling or forging, when once present they persistly remain, and may constitute incipient fractures.

If we should take a piece of steel free from blow holes or cavities, form it into a desired article for bridge or other structures, anneal it, and then dress its entire surface in a planer, giving it a polished surface, we should have a nearly perfect bridge building material; but as this would cost too much, it is desirable to see how we can most nearly attain the same result within practicable limits of cost and manipulative skill.

It is proposed to confer upon steel intended for structural uses the desirable qualities possessed by iron, by covering the steel with a shield of iron, which iron will protect the steel from surface injuries during the processes of manufacture and application. In a word, to make iron-clad steel for bridge building. By doing this we secure the effectual effacement of porosity and its train of evils; we secure a surface of metal in a condition that cracks, crevices, hammer marks, &c., will not become foci of vibration followed by fractures to a degree greater than with articles wholly made of iron. We gain incidentally a condition fitting our material for exposure in the furnace, by which we can obtain greater uniformity of carbon in the steel, and finally our metal is less sensitive to the evils of rough treatment through all the stages of manufacture and application. That is iron-clad steel, higher in carbon than thought safe for structural uses as naked steel, can be cut, punched and bent in a manner not admissable with the naked steel.

Besides commanding these advantages, a most important matter is the fact that iron-clad steel should be furnished cheaper than ordinary steel.

Theodore Cooper.—In closing the discussion upon this subject, I regret that certain points advanced by me, which I believe have two sides, were not questioned.

Two of the members have drawn attention to the use of high steel for steam hammer rods and similar uses as being of an opposite character of material from that I have claimed as proper for bridge purposes.

The writer has studied the experiments of Mr. Wm. Metcalf with much interest, and thinks he has made out presumptive evidence in favor of high steel for such purposes as he recommends. But he does not see the connection between the uses of high steel for resisting vibrations,

and low steel which must resist the stretching and compression due to the mechanical operations of the shop.

That a high steel would best resist the vibratory action induced by sudden changes of strains might almost appear as certain if we had not had it confirmed by experiments. The more elastic the material and the greater its range of elasticity—the less chance for its being overstrained and thus injured.

But no experiments have been made to show that high steel in irregular forms would be able to resist such repeated vibrations. On the contrary, all our experience goes to show that any sudden change of section in high steel is perfectly ruinous.

It will not stand the rough mechanical manipulations of punching, bending, straightening, &c, which bridge material has to go through. Only the mild, soft steel will give any favorable result under such treatment.

Mr. Macdonald says, why cannot we use 20 000 pounds tension upon high steel instead of the figures given in the paper? Because to use such a high unit of strain you must have a material which will not safely bear the treatment which *iron* bars have to pass through, and it is not justified by our present knowledge of the material, unless we use short pieces, and give them much more careful treatment than we do bars of iron which have a high ductility. The writer has not limited the strains in any other manner than by insisting upon a ductile material. If this can be obtained, the higher the tensile strength the better.

Mr. Torrey has put forward an iron-clad steel. This can only enter the competition as an unknown material, and must prove its capabilities before it can be considered as either iron or steel, of which we do know something. Whether two materials of different strength and ductility can be combined into a practically useful material is very doubtful, in the writer's opinion.

Mr. Clarke has presented us the results upon the use of steel for bridges in Holland. If he could also have given us the specified terms in regard to the quality of the material it would have been very instructive. It would appear as if the steel was the very kind considered in the preceding paper as unfit for bridge purposes. The plates used in these Dutch bridges were required to stand, *without* breaking or tearing, a strain of 82 000 pounds per square inch for a length of 15 minutes, which would require a material of *over* 90 000 pounds per square inch tensile

strength. Now, at the time these bridges were built, this would indicate a material that would have but little ductility.

No one would be more pleased than the writer could *experiment* show that we could venture safely into the use of high steel, but without convincing proof deduced from extended experiments it would, in his mind, appear very hazardous to attempt to throw away the factor of the ductility of iron and steel.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CLXXXVII.

(Vol. VIII.—October, 1879.)

THE CONSTRUCTION OF THE ATCHISON, TOPEKA AND SANTA FÉ RAILROAD OVER THE RATON MOUNTAINS, AND THE PERFORMANCE OF LOCOMOTIVES ON ITS STEEP GRADES.

By JAMES D. BURR, C. E., Member of the Society.

PRESENTED AT THE ELEVENTH ANNUAL CONVENTION, JUNE 17TH, 1879.

The railroad over the Raton Mountains, of standard 4′ 8½″ gauge, is a branch of the Atchison, Topeka and Santa Fé Railroad, under the names of Pueblo and Arkansas Valley, in Colorado; and New Mexico and Southern Pacific, in the Territory of New Mexico.

The Raton Mountains, a spur of the Sangre de Christo, or Snowy Range, extend nearly due east and west; while the Snowy Range, a portion of the Rocky Mountain system, extends almost due north and south, parallel to the direction of the road. The Ratons culminate in Raton (or Fisher's) Peak, 9 800 feet above the level of the sea, while the summit of Raton Pass is reached by the grade line at an elevation of 7 720 feet above the same plane.

A cross-section of the country from La Junta, Col., in the Arkansas Valley, to Las Vegas, New Mexico, over the line of the constructed road, is shown on Plate L. A map and profile of the Mountain Division, Trinidad to Willow Springs, is shown on Plate LI.

Plate LII, is a map and profile of the temporary track, or "Switchback."

Table 1 gives the distances, grades and curvatures from La Junta to Las Vegas.

Table 2 gives a statement of the progress of Raton Tunnel, kindly furnished by R. L. Engle, C. E., Engineer in charge of the construction of the Mountain Division, including Tunnel and "Switchback."

Plate LIII shows the Consolidation Engine, "Uncle Dick."

La Junta, Colorado, 555 miles west of Atchison, Kansas, at an elevation of 4 041 feet above tidewater, is the point where the Trinidad Branch of the Pueblo and Arkansas Valley Railroad diverges from the main line. This Branch extends to the boundary line of the Territory of New Mexico (97 miles from La Junta), at which point the New Mexico and Southern Pacific Railroad begins. This latter road is now nearly completed as far as Las Vegas, N. M., a distance of 118 miles from the boundary line.

From La Junta, Col., to Trinidad, a distance of 81 miles, maximum ascending grades of 60 feet per mile have been used, with adverse grades of 30 feet per mile. Curves of 1 146 feet radius are used, with a compensation or reduction of grades on curves at the rate of .05 foot each 100 feet, for each degree of curvature.

To preserve uniformity throughout, the following rules were adopted :

1st. Generally, the point from which to commence elevating the outer rail on curves, shall be on the tangent, 150 feet from point of curve, and shall attain its proper elevation at the point of curve.

2d. In cases of compound curves, or curves in the same direction where there is less than 300 feet tangent between curves, the same rule will apply,

3d. In cases of curves in reverse direction with only 100 feet tangent between them, the elevation shall begin at the point of tangent to the curve on the inner rail and attain its proper elevation at the point of curve on the outer rail, of the succeeding curve, and so, in an opposite sense, for the other rail.

There are thus on curves of this class, two planes inclined in opposite directions relative to the true grade line.

Profile N.M. & S.P. R.R. Summit to Las Vegas
Pecos Cap 8304
4390
Las Vegas 6161
Dixon BET Aqueducts & Rio Grande 6745
Sapello 6167
Las Junta 6371
Mora Canon
Dog Cr
Cherry Valley 6210
6432
Gallinas Cr
6330
Santa Clara 6134
6284 at BIG WINDY Gorge
Ocate 5000
5959
Cimarron 5745
6010
Tecolote Cr
Hess Ranch
Fresh Trail 6029
Valley
Utah 6356
Watrous Springs 6000
7767
7554
7000
6000
5000
NEW MEXICO
COLORADO
1000 feet

PLATE I.
TRANS. AM. SOC. CIV. ENG'RS
VOL. VIII. No. CLXXVII
HURR ON RAILROAD OVER
RATON MTS

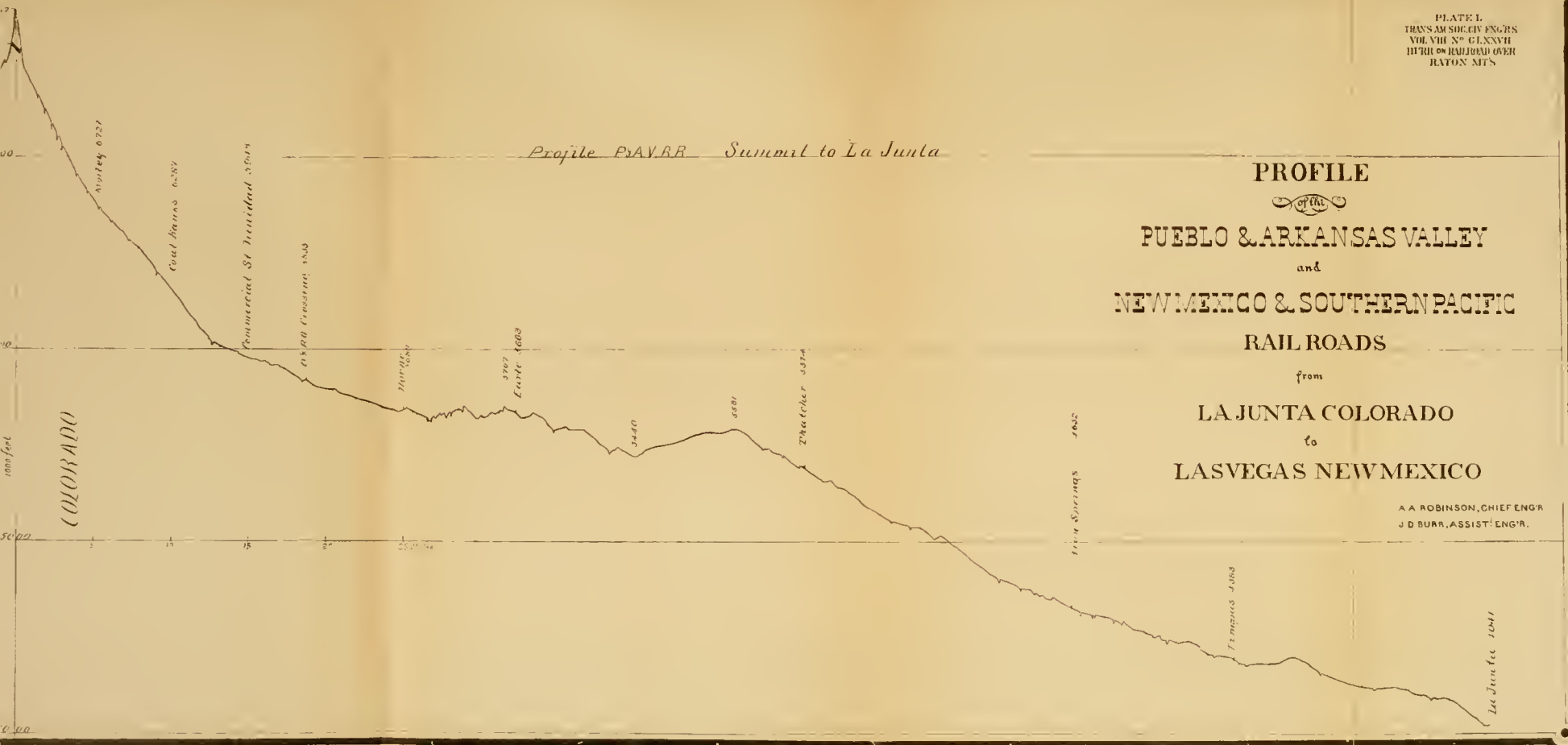


TABLE 1.

Distances, Grades and Curvature from La Junta, Col., to Las Vegas, N. M.

	Distance in miles.	Total Rise.	Total Fall.	Maximum Gradient in feet per mile.	Maximum Curvature degrees per 100 ft.	Total Curvature	Average Gradient.	Elevation Outer Rail per degree.	Compensation for Curvature in ft. per degree.	Remarks.
								Inches.		
La Junta to Trinidad.....	81.5	.....	.....	—30. +60.	5°	.....	.....	0.5	0.05	It is difficult to estimate the rise and fall of an engine with train, owing to the difference in length of train on the different stems.
Trinidad to Morley.....	10.1	800.	1.5	105.6	10°	865.1°	80.	0.5	0.05	
Morley to State Line.....	5.4	818.	.....	184.8	10°	945.°	151.4	0.5	0.05	
State Line to Willow Springs..	7.67	43.	990.	+184.8 —175.3	10°	1047.°	132.	0.5	0.05	
Willow Springs to Las Vegas..	110.25	.....	.....	70.	6°	.....	.....	0.5	0.05	
Switch Back.....	2.75	280.5	280.9	316.8	16°	1081.°13'	221.8 189.0	0.25	.....	

Plate L will show that there are but three short planes of descending gradients, of any considerable moment, between La Junta and Trinidad, going south, and as it was expected that there would be a large traffic in coal from Trinidad to supply the territory for 300 miles to the northeast, it was desirable to make the ascending grades, going north, as light as possible, consistent with economy in construction. In order to locate a line on 30 feet ascending grades to the north, from La Junta to Trinidad, —compared with the location of the Kansas Pacific Surveys made in 1871–72 on 70 feet maximum gradients *each* way,—a loss of 3 000 feet in distance was sustained.

From Trinidad the line follows the Valley of the Purgatoire—Picketwire, in frontier language—two miles to the mouth of Raton Creek. Thence, turning sharply to the south, with both maximum curvature and maximum gradients, it ascends the northern slope of the mountain proper by Raton Cañon, on two planes.

The first plane from the mouth of Raton Creek to Morley, eight miles, is nearly a uniform ascent of 105.6 feet per mile. At Morley, with an elevation of 6 727 feet above tide-water, a water-tank, turn-table and side tracks have been established. The yard is on a gradient of 1.66 feet per 100, or 87.65 feet per mile. At the south end of this yard the second incline plane commences, having 3.5 per cent. maximum grades. Between Morley and the summit there are three miles of maximum, supported grade. The average ascent is 151.4 feet per mile.

The summit is passed by a tunnel which, when completed, will be 2 011 feet long, located on 1.9 per cent. ascending gradient, going south. The south portal is 7 584 feet above the sea, and the top of the mountain proper has an elevation of 7 767 feet. Thus, in 306 stations of 100 feet each, there is an ascent of 861 feet, or a uniform ascending gradient of 2.8 feet per hundred. At the south portal of the tunnel the line commences to descend the southern slope of the mountain, on 3.32 per cent. maximum gradients, to Willow Springs, which has an elevation of 6 595 feet above tide, having made a descent of 990 feet in 38 400 feet, or a uniform gradient of 2.58 per cent.

On the mountain division, from Trinidad to Willow Springs, maximum curves of 573.7 feet radius are freely used. Maximum grades are compensated for curvature at a rate of .05 feet per degree of curvature, each 100 feet. The outer rail has been elevated at the rate of ½ inch per degree of curvature.

PLATE LI
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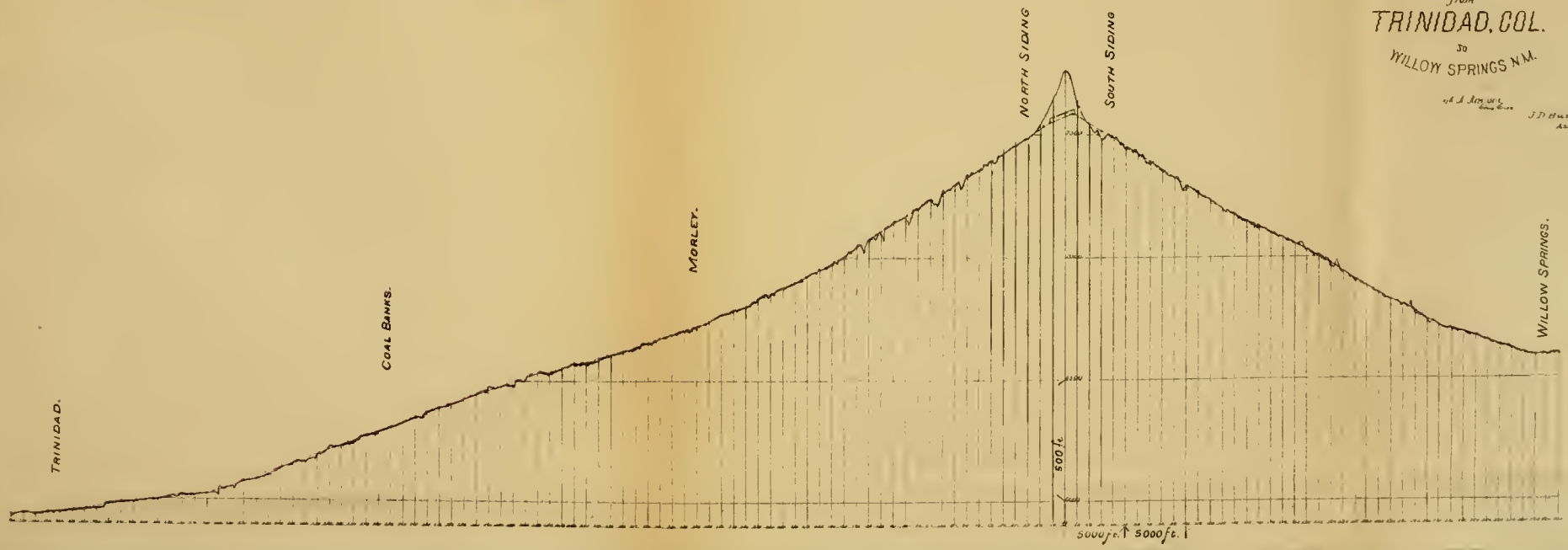
BITTER ON RAILROAD OVER
RATON MT'S

MAP
AND
PROFILE
of the
PUEBLO AND ARKANSAS VALLEY,
and the
NEW MEXICO & SOUTHERN PACIFIC
RAIL ROADS
from
TRINIDAD, COL.
to
WILLOW SPRINGS N.M.

J. D. Hurt
Asst. Engr.



From Willow Springs to Las Vegas, "The Meadows," 110 miles beyond, the line has been located on 70 feet maximum gradients with 6° curves from maximum curvature, on which the work of construction has so far advanced that Las Vegas will be reached early in July.

The surveys from La Junta to Willow Springs were begun on the northern slope of the mountains early in March, 1878, by A. A. Robinson, Chief Engineer, with George B. Lake (now Sup. Western Division) First Assistant Engineer, who made the location on the north side, while the location on the south side was made by R. L. Engle, Division Engineer in charge of tunnel. A company force was at once organized, and grading commenced.

The excavation at each end of the tunnel being very deep, 56 feet at the north portal, and 50 feet at the south end, mostly in solid rock, a shaft near the south portal was begun on June 1st. The shaft reached the roof of the tunnel section, July 9th.

On August 21st, the north approach had progressed so far that the heading was commenced at that end, but up to August 31st, only 73 feet of heading and 19 feet of full section had been driven, 14 feet of the latter being that allowed for the section of the shaft.

At this time the track had reached a point 65 miles south of La Junta, and it became evident that the completion of the tunnel must be hastened or a temporary track built over the mountains, otherwise track would be detained at the tunnel several months. It was, therefore, decided at the first meeting of any Board of Railroad Directors held in New Mexico, August 31st, 1878, to build a temporary track over the mountain, to be used until the tunnel could be completed. A location for a "switchback" was made immediately, and the grading for it, begun on the 16th of September, was completed in the latter part of November.

The maximum grade on tangent on the mountain top line is 6 feet per hundred; curves of 359.3 feet, least radius. Gradients are compensated for curvatures, on the switchback, as follows:

On curves of 1 146 feet radius and over, 0.05 foot per degree of curvature.

On curves of less than 1 146 feet radius to curves of 573.7 feet radius, 0.075 foot per degree of curvature.

On curves with shorter radii than 573.7 feet, 0.086 foot per degree.

The descent of the south slope is on a maximum of 4.9 per cent. on

straight portions of the track, compensated for curvature at the same rate as on the north side.

It will be noticed by reference to Plate LII that the ends of each stem (of which there are six, counting the two constituting the ends of the main line), are approached by ascending grades. This practice has proved a very desirable precaution; for, during the progress of construction a portion of a train became unmanageable on account of the wheels sliding down the frosty rails, and would have gone beyond the stem, and down an embankment many feet high, but for the resistance of the adverse grade. On May 12th an engine did go over the embankment at the end of Stem No. 2, on account of the brakes on the train giving way—although the engine was provided with air brakes on drivers—and there would have been a very serious accident, but for the resistance of the adverse grade. Fortunately the damage was slight, and only to the engine.

Before the close of December, 1878, the track had been laid over the mountain, and the work of transporting material for the construction of 118 miles of the New Mexico & Southern Pacific Railroad began. Besides this material, since the road has been opened for traffic, a period of three months, merchandise freight to the value of from $150,000 to $175,000 has been transported to and from the town of Otero, 12 miles beyond the summit. The average tonnage transported over the Switchback daily, since it was completed, may be stated, including dead weight, as, Tonnage South, 420 tons per day; Tonnage North, 200 tons per day.

At first the Switchback was operated by the ordinary eight-wheeled American engines with 17″ × 24″ cylinders, 60″ driving wheels, weighing about thirty-five tons, from the Baldwin shops, and with a 16″ × 24″ engine, same class as the first from the Hinkley shops, with 64″ drivers. The working of these light engines may be summarized as follows:

La Junta to Trinidad,	60. ′	grades,	14 to 18	loads of	43,000	pounds.			
Trinidad " Morley,	105.6′	"	8 " 11	"	"	"	"		
Morley " Tunnel,	184.8′	"	3 " 5	"	"	"	"		
" Switchback,"	316.8′	"	1 " 2	"	"	"	"		

The smaller number of cars being the number for the 16″×24″ cylinder engine; and the larger number of cars, the maximum capacity for the 17″×24″ cylinder engines.

PLATE LII
TRANS. AM. SOC. CIV. ENG'RS
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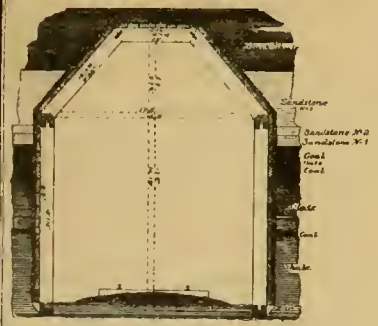
DURR ON RAILROAD OVER
RATON MT'S

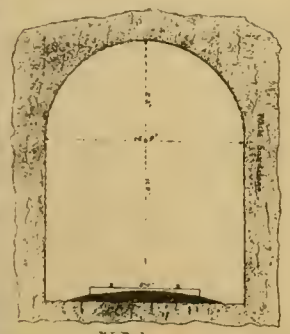
Map & Profile of the Main Line & Switchback over the Range RATON MOUNTAINS, N.M. & S.P.R.R.

Contour lines 15 ft. Vertical
Length Tunnel 2015 ft.
Hight of Tunnel 18 ft. 0 in.
Width " " 14 ft. 0 in.

NORTH PORTAL SEC.



SOUTH PORTAL SEC



Horizontal Scale

Vertical Scale = 1/10 Horizontal

N. L. Engle
Division Engineer

L. A. Robinson
Chief Engineer

The best day's performance of any of these light engines on the mountain division was that of Locomotive No. 106, from the Hinkley shops, with 16″ × 24″ cylinders, 64″ drivers. This engine left Trinidad, empty, at 7 A. M., for the Summit, 15 miles distant, and, during the day, took twenty-five loaded cars from the North to the South Siding, 2¾ miles, and brought back as many empty cars, and arrived again at Trinidad at 7 P, M. This was accomplished by taking one load from North Siding and leaving it at the summit; thence returning to North Siding for a second loaded car, and again, for its third load; then, from the summit, taking the three loaded cars to the South Siding. This performance was at the time considered remarkable.

The engine was provided with Westinghouse Air Brakes on driving and tank wheels, as are all engines which work on this mountain line. Engines which were fitted with the Automatic Brake have had the arrangement changed into the common Westinghouse Air Brake; it having been found that this last gives the best results in regulating the amount of force applied to the air brakes, and the air gauge of the air brake always indicating the pressure in the reservoir before the brakes are applied, as well as during the operation. On the other hand, with the automatic device it is impossible to tell the pressure until, and, during the application of the brakes, unless the pressure is kept up to the blowing off point. A very essential thing to know, in working the Mountain Top line, is that the brakes and brake power are in good condition and under perfect control.

The performance of two coupled engines on the Mountain Division has not been double that of engine 106, whose remarkable day's work was made at great risk; but, from 7 A. M. to 7 P. M., 34 loaded cars have been taken over from the North to the South Siding, besides 10 loaded cars hauled from Trinidad to the Tunnel, the engines returning to Trinidad within the time mentioned.

The advent of the "Uncle Dick," a "Consolidation" eight-wheeled-connected engine from the Baldwin shops, revolutionized transportation on the "Mountain Top" line.

The principal dimensions of this locomotive are:

Cylinders	20″×26″	Number of Tubes	213
Driving wheels	42″	Diameter "	2″
Total wheel base	22′—10″	Length "	10′—11¾″
Rigid "	9 feet.	Heating surface, fire box,	153□′
Diameter boiler, inside	57″	" " flues	1223.84□′
Length fire box	119″	Total heating surface	1376.84□′
Width "	33⅜″		

Capacity of tank on boiler ..... 1,200 gallons.
Estimated weight, including weight of saddle tank in working order ..... 115,000 pounds.
Estimated weight on drivers ..... 100,000 "

In this connection, it may be proper to say that "Uncle Dick" Wootten, the old pioneer after whom the locomotive is named, settled in the Raton Cañon in 1847 ; that he was with Fremont, Kearney, and Kit Carson ; and that he saw Fisher when he made his observations from the peak that bears his name.

The performance of this engine on the mountain division is as follows :

On the 2 per cent. incline, Trinidad to Morley—482½ tons hauled 8 miles per hour.

On the 3.5 per cent incline, Morley to Tunnel—258½ tons hauled 8 miles per hour.

On the "Switchback"—194 tons hauled 6 miles per hour, including time lost in opening and closing six switches. The foregoing weights do not include the weight of the engine.

On the 2 per cent. gradients the resistance is :

Gravity	$\frac{2\times2000}{100}$	=	40 pounds per ton.
Wheel friction		=	6 " "
Wind pressure	(say)	=	1.8 " "
Total resistance			47.8 " "

Traction = 482.5 + weight of engine say 60 tons = 542.5 tons.

Then, traction = 542.5 × 47.8 = 25,931 pounds.

Weight of engine on drivers = 100,000 pounds.

$$\text{Adhesion} = \frac{25{,}931}{100{,}000} = \frac{1}{3.86},$$

or somewhat greater than ¼ the insistent weight.

TABLE 2.

Progress of Headings and Enlargements of Raton Tunnel, N. M. & S. P. R. R.

1878. Months.	Shaft 8 Ft. by 14 Ft.				Heading North.				Enlargement North.				Heading South from Shaft.				Heading North from Shaft.				Enlargem't South Side.				Remarks.
	Feet.	Cubic Yards.	Labor Days.	Powder, lbs.	Feet.	Cubic Yards.	Labor Days.	Powder, lbs.	Feet.	Cubic Yards.	Labor Days.	Powder, lbs.	Feet.	Cubic Yards.	Labor Days.	Powder, lbs.	Feet.	Cubic Yards.	Labor Days.	Powder, lbs.	Feet.	Cubic Yards.	Labor Days.	Powder, lbs.	
June	31.0	128.6	318	720																					
July	21.0	87.1	493	1 230																					
August	11.8	48.9	327	1 613	18.0	72.0	160	288	.....	.....	.....	.....	25.0	75.0	260	337	16.0	48.0	180	240	5.0	31.9	30	104	¾ month in shaft. ¼ " " heading.
September	.....	.....	.....	.....	64.0	256.0	350	1 024	53.0	433.5	600	1 192	89.0	267.0	450	1 200	34.0	102.0	200	510					
October	.....	.....	.....	.....	59.0	236.0	338	944	62.0	507.2	606	1 395	.....	.....	.....	.....	60.0	180.0	416	900					
November	.....	.....	.....	.....	85.0	340.0	382	1 360	75.0	613.5	499	1 687	.....	.....	.....	.....	72.0	216.0	421	1 080	19.0	121.0	114	393	½ month in South Enlargement.
December	.....	.....	.....	.....	78.0	312.0	325	1 248	81.0	662.6	500	1 822	.....	.....	.....	.....	76.0	228.0	427	1 140	58.0	369.5	205	1 201	
Total progress	63.8	264.6	1 138	3 563	404.0	1216.0	1 545	4 864	271.0	2216.8	2,205	6 096	114.0	342.0	710	1 537	258.0	774.0	1644	3 870	82.0	522.4	349	1 698	
Best month	31.0	128.6	493	1 613	85.0	340.0	382	1 360	81.0	662.6	500	1 822	100.0	300.0	1 040	1 348	76.0	228.0	427	1 140	58.0	369.5	205	1 201	
Average	23.2	96.2	413	1 296	71.5	286.0	3 635	1 144	67.75	554.2	651.2	1 524	91.2	273.6	568	1 230	60.7	182.1	386.8	910	46.8	298.1	199.4	970	
1879.																									
January	.....	.....	.....	.....	103.0	412.0	416	1 648	84.0	687.1	600	1 890	.....	.....	.....	.....	84.0	252.0	442	1 260	92.0	586.0	653	1 904	
February	.....	.....	.....	.....	85.0	340.0	384	1 360	78.0	638.0	528	1 755	.....	.....	.....	.....	78.0	234.0	408	1 170	85.0	541.5	590	1 760	
March	.....	.....	.....	.....	97.0	388.0	410	1 552	104.0	850.7	654	2 340	.....	.....	.....	.....	94.0	282.0	460	1 410	96.0	611.5	665	1 988	From March 1, Hercules No. 2 principally used, but shown here as black powder, as 2½ is to 1.
April	.....	.....	.....	.....	90.0	360.0	400	1 440	100.0	818.0	650	2 250	.....	.....	.....	.....	116.0	348.0	552	1 740	145.0	923.6	899	3 002	
May	.....	.....	.....	.....	136.0	544.0	540	2 176	95.0	777.1	648	2 137	.....	.....	.....	.....	111.0	333.0	550	1 665	155.0	987.3	1000	3 208	
Total progress	.....	.....	.....	.....	511.0	2044.0	2 150	8 176	461.0	3770.9	3 080	10 372	.....	.....	.....	.....	483 0	1449.0	2412	7 245	573.0	3649.9	3807	11 862	
Best month	.....	...	.....	.....	136.0	544.0	540	2 176	104.0	850.7	654	2 340	.....	.....	.....	.....	116.0	348.0	552	1 740	155.0	987.3	1000	3 208	
Average	.....	.....	.....	.....	102.2	408.8	430	1 635	92.2	754.2	616	2 075	.....	.....	.....	.....	96.6	289.8	482.2	1 449	114.6	930.0	761.4	2 372	

On the 6 per cent. gradient:

Gravity.....	$\frac{6 \times 2{,}000}{100}$	= 120	pounds	per ton.
Wheel friction	=	6	"	"
Wind pressure	=	1.8	"	"
Total resistance....		127.8	"	"

Traction = 254 × 127.8 = 32,461 pounds.

$$\text{Adhesion} = \frac{32{,}461}{100{,}000} = \frac{1}{3.08},$$

or, slightly less than ⅓ the insistent weight.

The difference between the traction on the 2 per cent. and on the 6 per cent. gradients is explained by the fact that the locomotive has not been tested to her full capacity on the 2 per cent. gradients. The loads mentioned above were started from a perfect stand-still, and without taking the slack of the train, and without slipping drivers.

The best day's work on the Mountain Top Line with the locomotive Uncle Dick has been as follows: Left Trinidad for Morley at 7 A. M., with 15 loaded cars, besides tanks of coal and water; drew 10 loaded cars from Morley to Tunnel, and during the day took 46 loaded cars from the North to the South Siding, and brought back as many empties; reached Trinidad at 7 P. M. Time, 12 hours, of which 2½ hours were lost in waiting for trains and for meals.

The ordinary round trip, 5½ miles, requires 50 minutes time. The ordinary train consists of 7 loaded cars of 43,000 pounds each, tank of coal 44,000 pounds, and engine say 120,000 pounds. Eight loaded cars can be taken over at one time quite readily; and, at one time, nine loaded cars were taken at one trip, so that, during the day of ten hours, 6,020,000 pounds could, very readily, be moved over the mountain with one engine. It will be noticed that the capacity of engines of this class is more than double that of two American engines of 16″ × 24″ cylinders; while the quantity of coal consumed is but little more than that consumed by a single light engine.

As to the matter of controlling trains on these steep inclines it is a question of brake power and adhesion to the rail. In frosty weather, backing down an incline, the ordinary eight-wheeled engine, not having a sand pipe in the rear of its drivers, will lose its "bite" or adhesion to the rails, and slide down hill quite as readily as if placed on runners on

good sleighing. In such cases brakes are of small account. All engines should be provided with sand pipes placed so as to deliver sand on the rail, when going in either direction.

Under fair conditions of rail, one single hand-brake, in good order, to each car, together with the driver and tank brake, with three brakemen to a train of eight cars, is sufficient for safety, unless the train should acquire a speed of 18 to 20 miles per hour, in which event all the wheels in the train might be skidded far enough to lead to disaster.

With the Uncle Dick this danger is reduced to a minimum, for, as sand can be delivered along the rail in front of all the wheels, and two sets of air brakes may act on all drivers simultaneously with sufficient force to slide all the wheels, the maximum of adhesion is obtained.

The Uncle Dick is provided with water pipes for delivering a small jet of water on the flanges of each flanged driving wheel. In backing over the sharp curves of the "Mountain Top" line this jet of water is very beneficial in preserving the flanges of the drivers and also the head of the rails.

The "Switchback" is laid with 56 pounds iron rails, common splices, pine ties on straight line, oak ties at the joints of rails, and on all curves having less than 1,146 feet radii. A cast iron bracket fits up against the outer side of each rail on curves with 716 feet, and less, radii, while a guard rail of iron is placed on the inner side of the inside rail. These precautions hold the track in gauge.

The gauge of rails is 4′—8¾″ on straight portions of the track to 4′—9¾″ on the 16 degree curves.

The outer rail on curves was elevated ¼″ per degree of curvature per hundred feet. The track was operated with this elevation, for some time, when, it being noticed that the inner rail was becoming much kinked, an elevation of ⅛″ per degree was given. This proved to be an error, as, with this elevation, the Uncle Dick seemed inclined to leave the rail in the direction of a tangent to a curve, even at slow rates of speed; therefore, the original elevation of ¼″ per degree, on curves, was restored. This has given the best results.

During the first two weeks' work of the Uncle Dick its performance was anything but satisfactory owing to the frequency with which it left the rails at frogs and switches. This was caused, at the frogs by insufficient width of gauge and the inability to elevate the outer rail; at the switches partly by the insufficient weight of rails, partly by the

PLATE LIII
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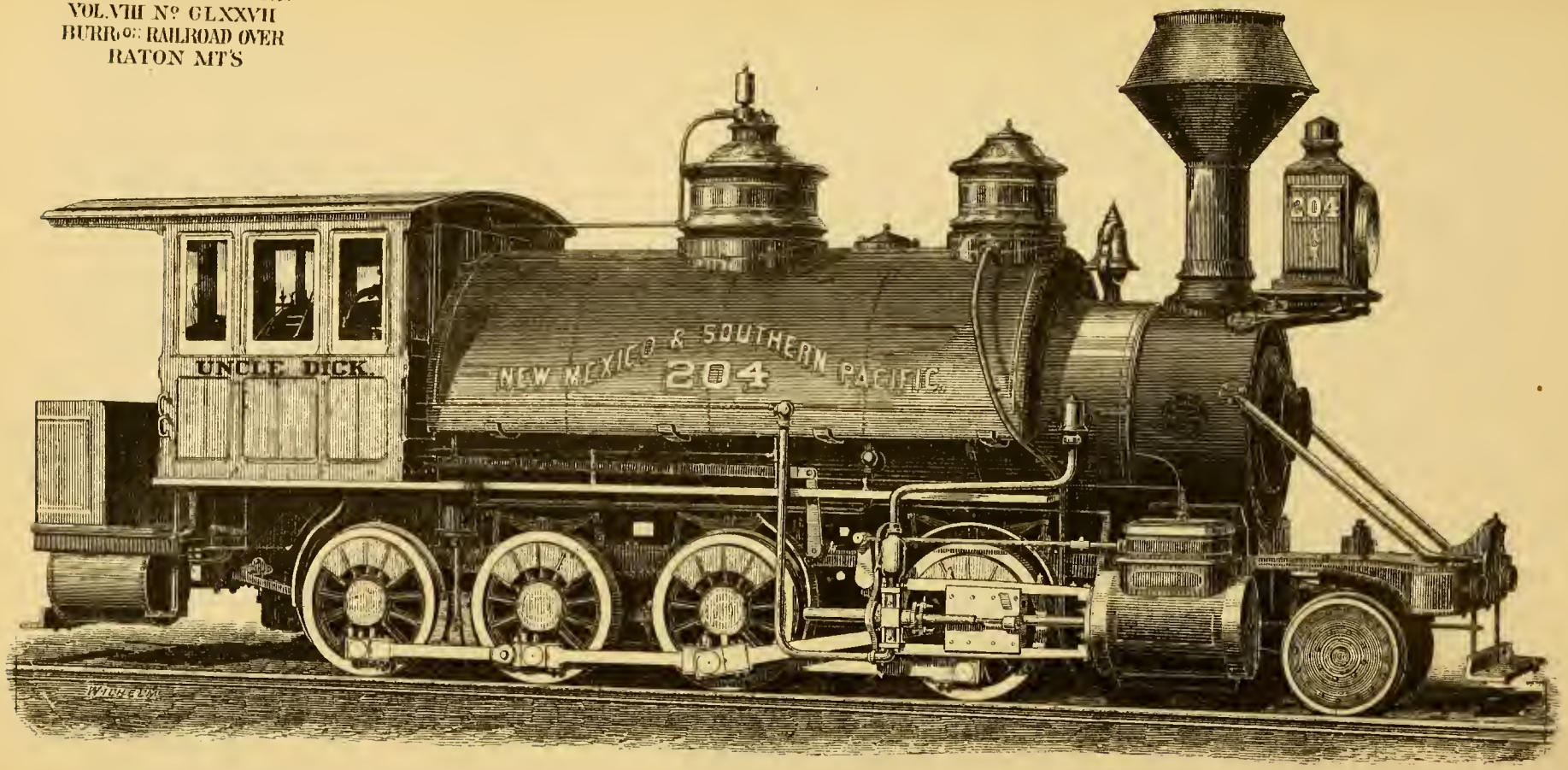
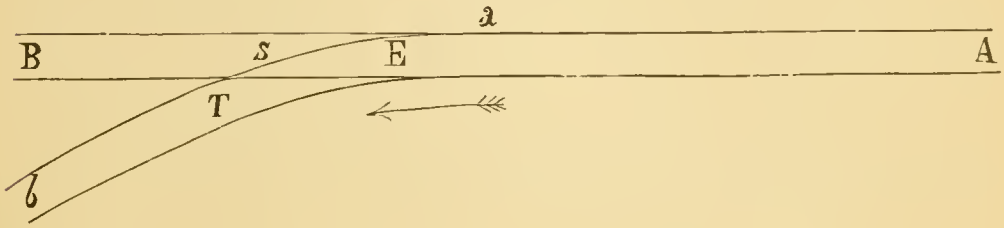
BURR ON RAILROAD OVER
RATON MT'S



small amount of play to the switch-rod connections, and very much by the great length and leverage between the trailing axle and the centre of the truck wheels under the tank.

From the plate of the locomotive Uncle Dick it will be seen that the original intention was to operate it as a tank engine. It was found, upon trial, that this could not be done with economy, therefore the ordinary tank was attached, and air brakes supplied in the usual manner.



If we suppose the figure to represent a portion of track near a switch with a descending grade from *A* to *B*, with the tank at *T*, engine at *E*, and the loaded train from *A* to *a*, moving in the direction of the arrow, and let the air brakes be suddenly applied to the tank wheels, the resultant of the two forces would throw the trailing wheel over against the slide rail *S* with sufficient force to cause a "lip" on the lead rail, and the engine would climb the lead rail and go over on to the main track.

This was obviated, in a measure, by taking off the coal bunker, reducing the length between engine and tank, and putting an additional set of air brakes on the drivers. At first there was but one pair of air brakes on the engine—those between the rear and next pair of drivers. These were used as little as possible, tank brakes being used instead, in order to preserve, as nearly as possible, the same diameter for all the wheels until the second pair of brakes could be supplied.

Since the foregoing defects have been remedied as much as possible, there has been no difficulty in working the Mountain Top Line, with the heavy engine. Indeed, it is believed that the Consolidation engine travels the 16 degree curves with as much ease as an ordinary American engine, and causes less wear of track and permanent way.

DISCUSSION

On the Paper "The Construction of the Atchison, Topeka and Santa Fê Railroad over the Raton Mountains," at the meeting of the Society, October 1st, 1879,

By J. Foster Flagg and Edward P. North.

J. Foster Flagg.—I have been looking forward with considerable interest to the appearance of the paper by Mr. Burr, but must confess to some disappointment in not finding therein more details of location and construction. I may, however, have overrated the difficulties of the former, which does not need, therefore, any especial description. The work of locating the developments of the track and the switch-backs of the Oroya Railroad, on the precipitous sides of the Rimac Valley in Peru, was one of exceeding difficulty,—which, by the by, I was in hopes we should have had a full description of long since from Mr. V. G. Bogue, Member of the Society, the engineer in charge of a division in the most difficult part of the route, he having intimated to me an intention of preparing a paper to this end several years ago,—and I may have been erroneously led to suppose there were similar difficulties here.

The details of grade and curvature are, however, quite valuable in connection with the performances of the consolidation engine, as a guide in estimating the possible capacity of roads in mountainous localities, where excessive grades and curvature have to be resorted to, whether as a temporary expedient or for permanent location. If the actual expenditure of fuel, etc., were given, we could also estimate closely the cost of transportation per ton mile.

On the Iquique and La Noria Railroad, in Southern Peru, and doubtless in other localities, the same expedient of laying the stem of the switch-back on a sharp up grade is resorted to, and its importance is very great in preventing or diminishing the number of accidents from runaway trains. This road has maximum grades of 4 per cent. only, but the great length of continuous steep descent makes the control of trains fully as difficult, probably, in the winter season, as upon the line over the Raton Mountain. From the station of Santa Rosa to the sea at Iquique, a distance of 17.2 miles, the track falls nearly 2 900 feet, an average of about $3\frac{2}{10}$ per cent. for the entire distance. Proceeding downwards from Santa Rosa, at the end of 7.7 miles, at Molle, the track,

being then about 1 600 feet above the sea, strikes the face of a steep cliff falling nearly to the ocean beach, and follows the face of the cliff for 7.5 miles to the only reversing station,—the remaining two miles having slight grades. There is thus a constantly descending grade for 15.2 miles, the average being at least $3\frac{4}{10}$ per cent. for this distance, with a maximum of 4 per cent., and very little less than 3 per cent. Although there is neither rain nor frost in this locality, there is in winter a very damp fog, which seems to impart a peculiar greasiness to the rails, making it very difficult to hold the trains, especially if they have once acquired any speed: and a train having fairly entered upon the *cuesta*, or face of the cliff, with a high velocity, the long distance to the reversing station, with numerous curves of 12° to 16° curvature on the way, renders its destruction almost certain.

After several severe accidents had happened on the *cuesta*, a switch was built at its head, on the pampa at Molle, to catch any runaway trains from above. This, like the switch-back, was built with a heavy ascending grade, with a self-acting split-rail switch, set to throw all descending trains upon the turn-out, and requiring the switch-tender, after throwing over the points *to hold them there* during the passage of a train in order that it might continue on its course down the main line. Notwithstanding this safeguard, a short time subsequent to its construction, by some stupid misunderstanding of signals, or lack of proper system in signaling, a train, of which the driver had lost control, came thundering by whilst the switch tender held open the path leading to its destruction. The result was an accident, which, with their insufficient appliances, blocked the road for five days, and a loss of life that would be appalling if its numbers could be stated; but the native railroad authorities managed to get the dead bodies of the poor friendless *peones* disposed of in some way, so that the amount of slaughter was never known.

At Sta. Rosa Station is a piece of level track, nearly half a mile in length, and above and beyond is the most difficult stretch of track on the road. Here, within a distance of 0.7 miles, are eight consecutive reverse curves, with no perceptible tangents between, with radii of only 330 to 570 feet—mostly under 400 feet—and with a total curvature of 535 degrees; it is all on a heavy ascending grade, a portion in the midst of the curves being 4 per cent.

In 1872 to 1874, when I was acquainted with the road, the locomotives were mainly Fairleigh's double enders, and it is interesting to compare

the performance of these much vaunted engines with that of "Uncle Dick."

The Hercules, one of the heaviest and best of Fairleigh's on the Iquique Railroad at that time, had the following dimensions:

Cylinders, 4 in number	15″ × 22″	Heating surface, fire box	138□′
Driving wheels, 12 do.	42″	" " tubes	1 543□′
Internal diam. of boilers	45″	Total heating surface	1 681□′
Length of each barrel	9′ 9″	Steam pressure in boilers	130 lbs.
Length of fire box	7′ 6″	Total weight empty	44 tons.
Width "	3′	" " with boiler filled	48 "
Height "	4′ 9″	Water carried in tanks (2 200 imp. gallons)	10 "
Number of tubes	286	Fuel in bunkers	2 "
Int. diameter of tubes	1¾″	Total weight of loaded engine	60 "
Length of tubes	11′ 1″		
Area of fire-grate	23□′		

Speaking from remembrance only, the above steam pressure was frequently much exceeded, to enable the engine to pull over difficult places.

As the engine first drew her supply of feed water from tank cars in the train, which were left on the way at sidings as emptied, its actual weight over the worst portion of the road must have been nearly her full loaded weight—certainly as much as 58 tons; and, like most of Fairleigh's engines, the entire weight was upon the 12 drivers. (The above weights and dimensions being from English sources, the tons are, doubtless, gross ones.)

The most difficult portion of the road below Sta. Rosa, where the engines were frequently stalled, and compelled to stop for some time to get up steam, is a 4 per cent. grade upon a reverse curve, the sharper curve being, I think, about 16° (not sharper than that), and more than long enough to receive an upward bound loaded train.

Assuming, with the author, an equalization of 1° in curvature with 0.05 foot grade per 100 feet—which, being equal to 1 lb. per net ton traction per degree of curvature, is a sufficiently liberal allowance, to say the least, on these sharp curves, in view of the experiments upon the Metropolitan Railroad referred to by Mr. Chanute (Trans. Am. Soc. of Civ. Eng., Vol. VII, p. 98,)—the work of the engine would be only that of hauling its train up $4\frac{8}{10}$ per cent. grade on a tangent.

Immediately above Sta. Rosa, the reverse curves above described, probably render the ascent more difficult from their length so reducing

steam pressure in the boilers, as to make it exceedingly difficult for a heavily loaded engine to pull through, even with the benefit of the speed obtained by a run upon the level track at the station, although the grade is no steeper nor the curves much sharper than at the most difficult point below Santa Rosa. It is probably equivalent to a $4\frac{9}{10}$ per cent. grade on a tangent.

As stated by the English superintendent of motive power and machinery at that time, the Hercules had taken up 150 tons (gross), but he considered this amount too much for the engine, and that 120 tons (gross) was a fair working load.

My own opinion, from frequent journeys over the road—although from the very promiscuous loading of the flats, it was difficult to judge of the amount of freight on each car—is that the latter estimate is quite a liberal one. I give as a sample the minutes of one trip, premising that all the cars were open flats, that the English ones were of ordinary English make on 4 wheels only, that the iron tank cars, also on 4 wheels, carried each about $10\frac{1}{2}$ net tons of water, that "Engineers' Camp" siding is a short distance above the Santa Rosa curves, and that from thence to the terminus at La Noria, the grades are moderate.

"Hercules left Iquique a little before 10 A.M., with three tank cars only; took on 3 loaded American and 1 loaded English car at the reversing station. Arrived at Molle ($9\frac{1}{2}$ miles) at 11 A.M.; took one more loaded American car, and left one tank after emptying it; two hours spent at Molle in transferring water, and *getting up steam.* Reached Engineers Camp (19 miles from Iquique) at 3 P.M.; 3 loaded English, 7 empty English, and 3 empty American cars added to the train, and one more tank left behind. Train arrived at La Noria ($33\frac{1}{3}$ miles from Iquique) at 6 P.M. Water being nearly exhausted (8 500 gallons taken up exclusive of boiler charge) engine returned without load."

Other engines of the same make were ordered, during the time spoken of, with 17 × 22 inch cylinders, 45 inch drivers, and 2 059 square feet heating surface, but I have obtained no record of their performance.

Edward P. North.—In the fall of 1868 I was directed to locate a line for a temporary track, eight miles long, around some heavy work at the head of Echo Canon, Union Pacific Railroad.

It was found advantageous to employ a grade of $145\frac{1}{2}$ feet per mile and two Y's in getting down into the valley of the creek that was followed. The stems of the Y's, which were long enough to hold seven

freight cars and a locomotive, had a grade of 145½ feet per mile against any train that came on them, and were extended in sharp vertical curves. At the foot of the heavy gradient, grading was done for a safety spring switch like the one described by Mr. Flagg, but track was never laid on it, as no difficulty was found in controlling the small trains that the Y's would hold. As far as known by the writer, this was the first instance in which such vertical curves were used.

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INTER-OCEANIC CANAL PROJECTS,

BY A. G. MENOCAL, C. E., Member of the Society.

READ NOVEMBER 19, 1879.

The object of the present paper is to present for discussion before the Society of Civil Engineers a question which is now attracting much public interest through the press of the country, and which deserves the most attentive consideration by the engineer, on account of its magnitude, the engineering difficulties involved in the solution of the problem, and the great interest the world at large has always shown, and will continue to show in the execution of the work.

It is evident that the American Isthmus has been sufficiently explored by the U. S. Surveying expeditions, and by private parties interested in opening a water passage, between the Atlantic and Pacific Oceans, to enable us to determine the difficulties that would have to be met in the construction of a ship canal at the several places pointed out as presenting favorable indications for execution, and on a careful examination of all the available data, the question seems to have narrowed down to Panama and Nicaragua as the only places where the work can be successfully carried out. It is to the discussion of the most prominent features of these two routes, and their relative advantages and disadvantages that I will confine myself.

Three projects for a canal at Panama have been seriously suggested and estimated upon, two at the level of the ocean, and one with locks. Of the first two, the one extending from the Bay of Colon to the Bay of

Panama has been devised by Lieuts. Wyse and Reclues of the French Navy, and lately advocated by M. de Lesseps, the successful promoter of the Suez Canal; and the other connecting the Bay of San Blas, on the Atlantic, with the Rio Bayano in the Bay of Panama, was first partially surveyed by Messrs. MacDougal and Sweet, in the interest of Mr. Kelly, and subsequently re-examined by Commander Selfridge, U. S. N., in 1871, and Lieut. Wyse, in 1878.

The project for a canal, with locks, *via* Panama, was carefully studied, and the line actually located by the U. S. Surveying Expeditiou, under Commander E. P. Lull, U. S. N., in 1875, of which the writer was the chief engineer.

Lieut. Wyse's Plan.

This project was first presented for discussion before the International Canal Congress, assembled at Paris, on the 15th of May of the present year, and is fully described by the author in his report to the president of the "Société du Canal Interoceanique," dated April 4, 1879. As originally projected it consisted of a thorough cut at the level of the oceans, 73 200 metres (45.5 miles) in length, 20 metres (65.6 feet) wide. and 8.5 metres (27.88 feet) depth of water, with a tunnel 72.20 metres (4.8 miles) long. The river Chagres, as well as the Rio Grande, and their tributaries to the number of 22, are to be received into the canal; the only provision made to ameliorate the effect of such an enormous volume of water is 191 000 cubic metres of excavation, in the beds of the streams at the several points of junction with the canal. The estimated cost of the work, as given by Lieut. Wyse, in his report, is 475 000 000 francs, or $95 000 000. This line is not one of actual location, but was traced on a map of the isthmus, between Colon and Panama, constructed from such information as could be obtained from the maps of the railroad and the survey of Mr. Garella, made in 1843 for a canal, with locks, on a location other than that adopted by Lieut. Wyse. The elevations of the ground given in the profile were also obtained, as near as practicable, from the same source of information, and the figures are, therefore, to say the least, a rough representation of the natural conditions.

This project was considered impracticable by the Technical Commission of the Paris Congress The sudden and high floods to which the turbulent river Chagres, and its tributaries, are subject in the rainy season, and the disadvantages under which those streams would have to be taken into the canal, on account of the elevation of their beds above

the sea, the proposed level of the canal, together with the current that would be produced in the canal by the rise and fall of the tide in the Bay of Panama (the spring tides amounting to 22 feet, would form such impediments to navigation, and so many serious difficulties, and doubtful elements in the execution and permanency of the work, that the plan had either to be modified, or abandoned altogether.

A sub-committee composed of the following distinguished engineers, viz., Messrs. Ruelle, Cotard, Couvreux, Favre, de Garay, Laroche, Lavalley and Lepinay were appointed to estimate on the probable cost of the tunnel designed by Lieut. Wyse. They reported that, supposing the work free from water, its probable cost would be about 38 500 francs per lineal metre, or $59 444 000 for the length of tunnel proposed, and with 25 per cent. added for contingencies, $74 305 000. But if the work had to be done under water, as it was thought would be the case in that portion of the excavation below the level of the sea, then the above estimate would be insufficient, and although the committee could not, in that event, arrive at the approximate cost, it was of the opinion that the expense would be increased by at least 100 000 000 francs or $20 000 000.

To meet these objections Lieuts. Wyse and Reclues submitted several plans, more or less feasible, from which the following modifications to the original plan were accepted and estimated upon. A tide lock at the Pacific terminus to keep the surface of the water in the canal at the mean level of the Atlantic ; an open cut in place of the tunnel ; and new channels to carry to the ocean the waters of the river Chagres, and its tributaries, from Matachin to the sea, independent of the canal, which should be kept entirely free from all surface drainage.

These modifications were considered as an improvement on the first plan; but the engineers differed widely as to the methods of execution and the practicability of the works proposed, at least, in a commercial sense.

The above-named engineers, on consultation with the sub-committee on locks and profiles, adopted uniform cross-sections and prices per unit of work for all the projects submitted to the congress, and the modified project was estimated according to the amount of work computed by Lieut, Wyse at $208 800 000, exclusive of the indemnification to the Panama Railroad.

The committee remarked in their report that such a sum had been obtained by applying the adopted prices for labor and material to the

quantities of work furnished them, increased by the sum of $8,400,000 named by the Committee on locks, as required, in its estimation for the canalization of the Chagres and its tributaries and necessary accessories, and added that the committee was of the opinion "that the execution of such works as the long, open cut proposed with a maximum depth of 321 feet above the surface of the water, and the construction of a new channel for the Chagres, the stability of which would not be assured, are subject to so many contingencies and difficulties that it was not possible to arrive at an estimate of their probable cost." The competency of the engineers hereinbefore named as composing that committee cannot be doubted; they are men of high established reputation for integrity and professional experience, and their figures and opinions are entitled to full consideration.

I have made careful computations with the object of ascertaining the amount of excavation required for the open cut proposed, and in order to arrive at as close an approximation of the cubical contents as the data at hand would permit, the profile of the route submitted to the Paris Congress by Lieut. Wyse, has been altered by the substitution of the line of actual location of the United States Surveying Expedition, from the Chagres river to the Rio Grande, in lieu of the defective profile of Lieut. Wyse.

It should be stated, however, that the length of the line has not been changed, and that by the profile adopted I have been able to base the computations on an elevation of the ground taken at every hundred feet between those points, and that the dividing ridge is crossed at an elevation of 294.7 feet above mean level of the sea, instead of 321.4 feet as given in Lieut. Wyse's profile. From Colon to the River Chagres, at Matachin, and from the Rio Grande to Panama, no alterations have been made, and the depths of the excavation have been taken from that profile. For the sake of comparison the computations have been made both according to the cross-sections proposed for the Nicaragua and Panama canals, with locks, and that recommended by the Committee on Locks at the Paris Congress.

The following are the results obtained, viz.:

1st. With the cross-sections adopted for the Nicaragua canal:

Excavation in rock above the level of the sea	61 329 477
Excavation in rock below the level of the sea	14 111 806
Total rock cub. yds.	75 441 283

Excavation in earth above the level of the sea	15 904 339
Excavation in earth below the level of the sea	7 046 970
Total earth cub. yds	22 951 309
Grand total of excavation in earth and rock, cubic yards	98 392 592

Besides this amount, there will be required no less than 1 800 000 cubic yards of rock excavation under water in the bays of Colon and Panama.

2nd. With the cross-section recommended by the Paris Congress:

Excavation in rock above the level of the sea	38 821 559
Excavation in rock below the level of the sea	11 741 022
Total rock, cub. yds	50 562 581
Excavation in earth above the level of the sea	14 694 916
Excavation in earth below the level of the sea	8 667 733
Total earth excavation cub. yds	23 362 649
Grand total of excavation in rock and earth	73 925 230
Or cub. metres	56 183 174

Which is 10 000 000 cubic metres in excess of the total amount of excavation estimated by Lieut. Wyse for the Paris Congress, on the same cross-section. The amount of rock and earth have been computed according to the geological profile submitted by Lieut. Wyse. It will be observed that the total cube of excavation required with the cross-section proposed by the Paris Congress, is about 25 per cent less than the amount obtained by adopting the cross-section proposed for the canal by Nicaragua. This is due to the insufficiency of the slopes for rock allowed by the Congress, viz : a vertical cut below and two metres above the water line, and an inclination of one-tenth above that point to the top of the rock. On the Nicaragua route one-half horizontal to one vertical, from the bottom of the canal to ten feet above the water, and one-fourth horizontal to one vertical above that point to the top of the rock, were considered necessary to obtain the permanency of the works, and they were so adopted throughout the line. The water prism for the canal in rock proposed for the Nicaragua line is 2 418 square feet ; that recommended by the Congress is 2 012 square feet. Nevertheless, it has been repeatedly stated by the friends of the Panama scheme that the

dimensions proposed for the Nicaragua route are insufficient for a ship-canal, and that to this fact is due the large difference in the estimated cost of the two routes. It is well known to those informed of the variable geological formation of the isthmus, as observed in the digging of wells, excavations for railroads, gold and siver mines, and other works, that vertical cuts and slopes with an inclination of one horizontal to ten vertical are impracticable for the proposed work with a total length of continuous deep cut of 41⅓ miles, with an extreme depth of 322.5 feet above the bottom of the canal, and a mean depth of 174 feet for a distance of ten miles.

The amount of excavation herein given is exclusive of what may be found necessary to provide a new channel for the river Chagres and its tributaries from Matachin to the sea, a distance of 28 miles, as recommended by the Congress. No data has been obtained to enable us to arrive at an approximate cost of that work, estimated by the Congress at $3 400 000. The engineer may, however, appreciate the magnitude of that undertaking from the fact that the river Chagres, at Matachin, the point of its confluence with the canal, rises about 36 feet in times of flood; that the bed of the river is about 40 feet above the level of the sea, and has an inclination of 4½ feet per mile for a distance of 12 miles above that point. That the channel attains a width, in times of flood, of 1 500 or more feet, a sectional area of 15 000 square feet, a current of 7 miles an hour, and a discharge of about 160 000 cubic feet per second. The inclination of the bed decreases considerably below Matachin, and as its volume is materially swelled by the addition of affluents with large flow, the sectional area of the new channel will have to be increased in proportion. Below Matachin the river, for a distance of 10 miles, runs in a narrow valley confined by high precipitous hills, approaching from both sides. This valley is to be occupied by the canal, the width of which, at the top of excavation, will be about 500 feet. The new channel for the river will, therefore, have to be cut through the high hills on the north, and protected across the narrow valleys by heavy embankments, and, in some cases, masonry walls. Similar difficulties, but on a smaller scale, will have to be met on the south side of the canal in canalizing the river Trinidad and other large streams, tributaries to the Chagres from that side.

The difficulties and contingencies involved in the execution of such works, considering the location, climate, rainfall, etc., cannot be approx-

imately estimated with our present information. Their stability, if ever completed, could not be assured, as they will be constantly menaced with total destruction by the periodical floods of the rivers.

Canals with Locks from Colon to Panama.

In 1875 the Government of the United States, at the request of the Commission appointed by the President to examine the different surveys made for an Inter-Oceanic Canal, and to report as to the line possessing the greatest advantages, sent out an expedition to ascertain the practicability of a canal, with or without locks, across the Isthmus of Panama. In a preliminary examination of the route, it was observed that the high water marks of the river Chagres, in the vicinity of Matachin, disclosed the fact that the river was subject to freshets, which raised its surface to no less than 36 feet above its level in the dry season, which latter was 42 feet above the sea. All idea of a canal without locks, or of utilizing the bed of the river for ship navigation, was therefore abandoned, and attention was directed to the location of a canal with locks that would cross the river at such an elevation as would give a free flow underneath to the highest floods. The summit level of the canal was, on that account, fixed at an elevation of 123¾ feet above the mean level of the sea, as follows:

Elevation of highest water mark	77.70
Rise of arch	14.05
Thickness of arch	6.00
Depth of water in the canal	26.00
Elevation of summit level, feet	123.75

The river is proposed to be crossed by means of an aqueduct having 12 spans of 90 feet each, 1 900 feet extreme length, 65 feet wide and 26 feet deep.

The water to supply the canal will have to be obtained from the upper Chagres by means of a feeder 10¼ miles long, and involving seven tunnels with an aggregate length of 13 700 feet, and two siphons of 4 530 feet and 12 000 feet in length, respectively.

Careful gauges of the river Chagres, on the 15th of March, 1875, showed the discharge, at the point the feeder leaves the river, to be 55 900 800 cubic feet per day : an amount of water sufficiently large to supply the canal with 80 lockfulls per day, and to amply provide for evaporation, leakage and filtration. In the month of April of the follow-

ing year, in passing across the Isthmus, I had occasion to observe that the river was lower, by at least one-third than at the time when the gauges were taken the previous year. Should my estimate be correct, it would evidently show that the supply, to say the least, could not be relied on at all times.

The line was carefully located from the Atlantic to the Pacific, developing an extreme length of 41¼ miles. The dividing ridge was crossed at an elevation of 294′.7 above mean half tide, giving an extreme depth of excavation of 171′, plus the depth of water in the canal.

One tide lock is proposed in the Bay of Panama, and 24 lift locks, 12 on each side, of 10.3 feet lift each. The latter were located at those points offering the greatest facilities for construction, with a saving in the excavations. The form and dimensions of the cross sections for excavation in earth and rock, as well as the prices adopted, were for purposes of comparison exactly the same as had been recommended for the Nicaragua route. The estimated cost, including the necessary improvements in the bays of Colon and Panama, was found, on carefully made computations to be $94 511 360. Of this amount, $18 331 343 are estimated for the construction of 16 culverts and the necessary side drains to dispose of the surface drainage independent of the canal. The disadvantages of this route are: the length of tunneling and siphon required for the feeder, a doubtful supply of water, an aqueduct 1 900 feet long, swamp lands to be traversed by the canal, large mean annual rain fall of 124 inches, and total lack of building material of all kinds fit for the construction of the works recommended. The advantages are: short route from sea to sea, and fair harbors on either side. The railroad, in close proximity to the projected line, is a favorable condition, provided that its owners are willing to give up their franchise for all purposes at the cost of construction or a reasonable consideration, upon which I will not venture an opinion.

The San Blas Route.

This is well known to be the shortest route between the Atlantic and Pacific Oceans; a favorable feature which, with an excellent harbor on the Atlantic side, has always attracted the attention of those interested in the solution of the problem of interoceanic canal communication. The line has not been surveyed throughout its length, but from the partial examinations made by Mr. MacDougal, in the interest of Mr. Kelly of New York, in 1864, and by Commander Selfridge in 1871, its total

length has been approximately placed at 30 miles, of which from seven to ten miles will require tunneling.

Based on information obtained from these surveys, plans have been prepared for a canal at the level of the sea, the cost of which was estimated by the Paris Congress at $261 536 595, the tunnel having a section of 1 315 square yards and a length of 8.7 miles.

The main objection to this route is the long tunnel required to pierce the Cordilleras separating the two oceans, having an elevation of from 1 100 to 1 500 feet.

The available data is not sufficient to enable us to determine the probable cost of that work ; but it seems to be generally admitted, it will be so large as to exclude it from the number of practicable schemes, at least in a commercial sense. There is no doubt that great difficulties would have to be met in the opening of a tunnel of the dimensions proposed for ship navigation, and it seems to be equally true that almost all the plans suggested to overcome them have been based on assumptions as to the natural conditions. The limited knowledge we have at present of the geological formation of the isthmus has been gained from examinations of surface indications, deep wells, gold and silver mines, the excavations for a few railroads, at far distant points, and the banks and beds of streams. Some of the printed reports on the subject rest on mere superficial observations of only some of those sources of information. For example : a geologist accompanying one of the expeditions follows the *trail* of the surveyors for a distance of 10 or 12 miles, from the coast by the traverses, collects a few specimens of rocks and pebbles from the beds of the streams, takes some notes on the variable character of the soil and rocks cropping out here and there, and returns by the same way to tell us the *fact*, "that the Atlantic slope of the Cordillera in the vicinity of San Blas is composed of the older crystalline rock, such as granite, syenite and diorite, while that on the Pacific side belongs to the later eruptive period, and its rocks belong to the families of the trachyte and of the basalts, etc., etc." Had he gone but a few miles to the west he would undoubtedly have found at the head waters of the Chagres, deep gulleys or cañons cut in a continuous mass of soft lime stone ; and not far from there, blocks of trap rock and other varieties of stone, which might have somewhat modified his conclusions. Information so superficial as the above does not seem to "afford a sufficient guarantee that the rock to be met with in piercing a tunnel on the San

Blas route will, for the most part, prove to be of a character sufficiently homogeneous and firm to be self-sustaining," as has been assumed in computing the cost of a canal by that route. We have not the data to affirm that the contrary will be the case; but the indications are, I believe, pointing to that conclusion, and the chances are, to say the least, just as much in favor of as against it.

The only way to arrive at the information required for the proper understanding of the subject, and to obtain the data for a fair estimate of cost, would be by sinking a number of shafts to the bottom of the canal on the line of the proposed tunnel. In this manner the character of the rock, and the quantity of water that would flow into the excavation when made, can be approximately determined. Boring with the diamond drill would show the character of the material to be met with, but would not furnish satisfactory information as to filtration. Until that is done the question may be considered as resting on mere *guessing*, in which the opinion of those who have been on the ground and gained information by actual observations should be entitled to most consideration. It is certain that in the construction of an isthmus ship canal at the level of the sea, it will be necessary to contend with water from filtration. This can be drained to the lower levels, while the bottom of the excavation is sufficiently high above the sea to allow the flow by gravitation; but below that level the work will probably have to be done under water.

Pumping by different processes has been suggested as a means to overcome this difficulty, but the experience acquired from a close observation of what takes place in deep mines and in wells dug to a great depth, leads us to believe that such a recourse would be found altogether insufficient, even after dividing the tunnel by bulkheads into a number of small sections. Should these fears prove well founded, it will not be possible to approximately estimate the ultimate cost of such an undertaking. The Engineers of the first committee of the Paris Congress, of which Mr. Favre, the eminent engineer of the St. Gothard tunnel was a member, were of the opinion that such a contingency would increase the cost of the work by at least $20 000 000. In case the excavations below the level of the sea were carried under water, the men and machinery would have to work from scows, and the debris dredged and deposited in dumping scows to be disposed of at the ends of the canal: while all these operations of drilling, blasting, dredging and transporting would have, necessarily, to be done within a width of from 66 to 100 feet,

according to the dimensions proposed for the tunnel by different parties. Should it be found, as is apprehended by many, that the material met with is not self-sustaining and that the tunnel will have to be totally or partially lined with masonry walls resting on the bottom of the canal, the problem will become so complicated that a favorable solution may well be despaired of. That work would have to be done by underpinning from the crown of the arch, carried down to a depth of 28 or more feet below the surface of the water, and for a distance of several miles. By what methods it may be accomplished has not yet been explained. The advocates of a thorough cut are not disposed to admit that these contingencies are likely to be met with, and even deprecate the idea that the chances are just as much in favor of as against them. They will continue to base their estimates on the assumption that the waters from filtration will be no serious obstacle to the prosecution of the work to a depth of 28 or more feet below the level of the sea, as it may be readily disposed of by pumping ; that the material will be self-sustaining and sufficiently firm so that no lining of masonry, to speak of, will be needed to secure the stability of the tunnel, and that an inclination of one horizontal to ten vertical will be enough for the slopes of cuts 300 or more feet in depth.

From the above considerations it seems to follow, that the bottom of a canal across any portion of the Isthmus, should be placed sufficiently high above the sea to obtain natural drainage, and that without this condition the work may be considered impracticable on account of its immense cost. This modification involves the necessity of three or more locks on each side, which may not materially change the length of the tunnel, but is sure to considerably reduce its cost by the elimination of unknown quantities in this difficult problem.

The Nicaragua Route.

This line was carefully located from the Atlantic to the Pacific Oceans by the United States Surveying Expedition, under Commanders Hatfield and Lull, United States Navy, during the years 1872 and 1873, and is fully described in the official reports submitted to the Secretary of the Navy in 1873. I was Chief Engineer of these expeditions from the commencement of the surveys to the time the reports were completed, and have subsequently visited the country on three different occasions, and made extensive surveys in connection with this work, and the improvements of the navigation of the river San Juan. I have, in fact, given

close attention to the subject for a period of eight years. The estimates of cost were based on the data obtained from a line of actual location. Elevations of the ground were taken every 25, 50 or 100 feet; and sufficient cross sections, soundings, and gaugings of streams, borings of the ground to the bottom of the canal, or until rock was met with, and such other additional information as to building materials and means of communication as were needed to arrive at a fair valuation of the probable cost were obtained. Nothing was taken for granted, in the formation of the project; therefore, any changes of location introduced hereafter by a more detailed final survey, will, with perhaps one exception, reduce the original estimates.

This exception refers to the enlargement of all curves of less than 5 000 feet radius, objected to by some engineers, as too abrupt for a ship canal. Distinguished officers of the United States Navy were consulted as to the proper radii to be adopted, and they were of the opinion that 2 200 feet should be the minimum sufficient for the free passage of vessels 400 feet long. The following curves with the radii named were, in consequence, located, viz., 1 of 2 200 feet, 3 of 2 500 feet, 11 of 3 000; 1 of 3 500 and 3 of 4 000 feet; all others have a radius of from 5 000 feet to 10 000 feet.

During the presentation of this route in the session of the 17th May of the Paris Congress, I was asked by M. Voisin-Bey, what, in my opinion, would be the additional expense involved in increasing the radii of the curves. I am reported in the printed proceedings of the Congress, as saying in reply, that $28 000 000 would be the probable cost demanded by the change. I do not remember what my answer was to that question, but it will be apparent to any one, that I could not have estimated so comparatively small additional work, at more than one-half the estimated cost of the whole canal. I believe that $1 800 000 would be a liberal allowance under the most unfavorable conditions. I have referred here to this subject because a writer in the *Bulletin du Canal Interoceanique*, a paper published in Paris, in the interests of the Panama scheme, has made a point of that evident typographical or reporter's error, and seems to doubt the accuracy of some of the figures embraced in the estimate of the Nicaragua route, which he could easily verify by computation from the elevations given in the profile of the line, and the cross-section recommended. He will also find in this paper an answer to his statements as to the cubical

amount of excavation required for both the Nicaragua and the Panama line. Lake Nicaragua, the proposed summit level of the canal, is 110 miles long by 30 miles wide, and is situated at $107\frac{63}{100}$ feet above the mean level of the ocean. Several trial lines were surveyed from the lake towards the Pacific, and on careful comparison of their relative merits and elimination, it was decided that those connecting the mouths of the little streams, Lajas and Del Medio, with the port of Brito, presented the greatest advantages on account of their moderate lengths and the comparatively low depressions by which they crossed the dividing ridge.

On a careful location, those lines were found to have an extreme length from the lake to the Pacific of 18.52 miles and 16.33 miles respectively for the Lajas and Del Medio routes. The divide was crossed at an elevation above mean high lake of 43.78 feet by the first and 134 feet by the second named lines. Considerations of better drainage and shorter distance decided us in favor of the Del Medio route, and the estimates of cost herein submitted are based on the data obtained from the survey of the same. The difference in their locations is comprised between the lake and a place called Las Serdas, where the level of the lake, if continued, would meet the Pacific Slope, thence to the Pacific, a distance of 8.33 miles, they form one and the same line. Should it be disclosed by a more detailed survey that the difficulties presented by the Lajas line for a good system of surface drainage can be overcome at a moderate expense, that would certainly be the most advantageous of the two, on account of a small extreme depth of cut through the divide and consequent reduced cube of excavation and cost.

The level of mean high lake is 103.14 feet above high tide at the port of Brito, an elevation to be overcome by ten lift locks 400 feet long between gates, 70 feet wide and 10.31 feet lift, located in a distance of eight miles. The depth proposed for the canal is 26 feet, and the width at the surface of the water 150 feet in earth and 106 feet in rock, with slopes of $1\frac{1}{2}$ horizontal to one vertical for earth and $\frac{1}{2}$ and $\frac{1}{4}$ horizontal to one vertical for rock.

The lake navigation extends from the mouth of the river Del Medio to Porto San Carlos, the head of the River San Juan, a distance of 56.5 miles. The river San Juan is proposed to be made navigable by means of four dams, and short canals and locks to pass them, for a distance of 63.02 miles to the confluence of the river San Carlos, the first large tributary of the San Juan. At this point the canal leaves the river, and

is located on its left bank for a distance of 26.90 miles, where it turns to the north, and by an almost straight line reaches Greytown, with a further distance of 15 miles, or a total length of 41.90 miles from the point where it leaves the river at San Carlos. This river it is proposed to divert, so that its discharge into the San Juan shall be below the last dam, and thus keep out of the canal its muddy and silt bearing waters. Ten lift locks of 10.87 feet lift are estimated for this side, three of which are located on the short canals around the dams.

The following table will show the position, and length, height, and other particulars of the dams :

Location.	Distance from Lake, in miles.	Length of Dam, in feet.	Height above bottom of River, in feet.	Height water is raised in front of Dam, in feet.
1. Castillo	37.34	940	21.01	18.87
2. Balas	44.69	1 196	31.92	22.82
3. Machuca.....	50.57	824	33.99	26.84
4. San Carlos.....	66.81	1 000	30.97	23.87

The first three dams rest on rock foundation and rocky abutments. The last one will rest on a hard and compact gravel bottom, and is intended to be protected by an apron to prevent the undermining effect of the fall. They are designed to be built of concrete, and so constructed that the water in the river will not be raised until the structures are completed in all their parts. This is expected to be accomplished by leaving sluices in the dams sufficiently large to afford a free passage to the river at high water, and to be closed by suitable gates on the upper sides when the dam is ready to receive the pressure intended. The river will be backed to the lake, the surface of which will be raised from three to four feet, and I estimate that it will take about four months for the river to reach the top of the first dam.

In the meantime the openings in the dams may be closed from the lower side, and the material will have sufficient time to set, before it is brought in contact with the water.

This method of construction will have other advantages in the construction of the canal.

It will permit the dredging and rock excavations under water to be done at a moderate depth, and allow the construction of the short canals and lift locks around the dams, free from the high water of the river.

The total length of the line from Greytown, on the Atlantic, to Brito, on the Pacific, is 181.26 miles, divided as follows :

Inland Canal.

	Miles.
From the mouth of river Del Medio, at the lake, to Brito	16.33
Short canal around Dam No. 1 across the river San Juan	0.78
Short canal around Dam No. 2 across the river San Juan	1.57
Short canal around Dam No. 3 across the river San Juan	1.16
From Dam No, 4, below the river San Carlos, to Greytown	41.90
Total length of canal	61.74
Lake navigation	56.50
Slack water navigation by the river San Juan	63.02
Total miles	181.26

The following is a recapitulation of the estimated cost, viz. :

WESTERN DIVISION.

From the mouth of the River Del Medio to Brito, 16.33 miles.

Excavation and embankment	$16 787 566
Ten lift locks, 400 feet by 70 feet by 10.37 feet lift	3 957 818
One tide lock, 400 feet by 70 feet by 9.00 feet lift	421 306
Drains, grubbing and clearing, &c.	514 087
Total for Western Division	$21 680 777

Middle Division, or lake navigation, 56.50 miles.

Dredging in mud and gravel and excavation in rock	$715 658

Eastern Division, from the Lake to Greytown.

Slack water navigation, 63.02 ; Inland Canal, 45.41 = 108.43 miles.

Excavation and dredging in the river	$5 076 030
Short canals around dams	1 056 922
Excavation and embankment in canal, from Dam No. 4 to Greytown,	13 389 398
Dams Nos. 1, 2, 3 and 4	1 543 526
Lift locks, from 1 to 10, inclusive	3 093 160
Drains	340 400
Diversion of San Carlos river	283 578
Grubbing and clearing (2,379 acres)	237 900
Total for Eastern Division	$25 020 914

RECAPITULATION.

Western Division	$21 680 777
Middle or Lake Divison	715 658
Eastern Division	25 020 914
Harbor of Brito	2 337 739
Harbor of Greytown	2 822 630
Total	$52 577 718
Add 25 per cent. for contingencies	13 144 429
Grand total	$65 722 147

There are about 10 807 cubic yards of rock excavation estimated for, at the west side of the Lake, which would have to be blasted and dredged out at a depth of twenty-six feet below the level of the water in the canal or twenty-two feet under water in the lake, at the time of doing the work. This has been estimated for at $5.00 per cubic yard, which is thought a liberal price, considering that the rock is not a hard solid mass, but boulders and blocks. Col. Childs' estimate of the same work in 1851, when our present means for doing this kind of work were unknown, was from $2.50 to $5.00 per cubic yard. There are also 834 992 cubic yards of rock excavation, and dredging in the river at depths varying from nine to fourteen feet, which has also been estimated for at $5.00 per cubic yard. Much of this material is loose rock, and the whole would be removed before the river is raised by the dams.

The actual cost of some rock excavation in the River San Juan, at a depth of six feet, done recently on a small scale and with scanty means at hand, has been $2.50 per cubic yard of rock deposited on the banks; and I have been told by Mr. A. C. Rand of New York, that rock blasting and dredging to a great depth (from sixteen to twenty-four feet,) is now being done in the River St. Lawrence, at a cost of less than $5.00 per cubic yard.

The total amount of excavation, dredging and embankment, exclusive of the harbors estimated upon, may be given as follows:

Excavation in earth, cubic yards	32 433 797
Excavation in rock, cubic yards	14 435 477
Dredging in the lake and river	4 855 935
Embankment	7 262 629
Excavation in rock under water	845 719
Total cubic yards	59 833 557

Deducting from this total cube the embankment which will be constructed with the material proceeding from the excavation, at a small additional expense over that for transportation, we will have 52 570 929 cubic yards as the total amount of excavation and dredging required, or 45 800 000 cubic yards less than the computed volume for the Panama Canal, *a niveau*, with the same slopes and cross-section.

Computing the cubical contents according to the cross-sections proposed for open cut, and a bottom width for the channel in the lake and river of 100 metres (328 feet), as recommended by the Paris Congress, we obtain a cube of earth and rock work of 53 793 982 cubic metres, or 70 663 000 cubic yards, an increase in the total amount of 10 947 998 cubic yards, as shown in the following table :

CUBICAL CONTENTS OF EXCAVATION IN CUBIC YARDS.

	With Cross Section of Paris Congress.	With Cross Section for Nicaragua Line.	Increase.	Decrease.
Excavation in earth	31 535 500	32 433 797	.....	898 297
Excavation in rock	10 393 537	14 435 477	.....	4 041 940
Dredging in the river and lake	18 209 722	4 855 935	13 353 787	
Excavation in rock under water	3 380 167	845 719	2 534 448	
Embankment	7 262 629	7 262 629	.....	
	70 781 555	59 833 557	15 888 235	4 940 237

This increased amount of excavation is due to the enlargement of the bottom width of the channel in the lake and river from 80 to 328 feet. The width of 80 feet at the bottom of the channel, with slopes of six horizontal to one vertical, I consider ample for all practical purposes. In fact, a vessel drawing 24 feet would have a channel of 104 feet in width, and for one drawing 20 feet the width would be 152 feet. I cannot see why the channel in the river and lake, if properly marked, should be much wider than in the inland canal, inasmuch as there is no perceptible current in the lake, and that in the river will not exceed one mile per hour after the improvements are completed.

I had occasion to call the attention of the first sub-committee of the Technical Commission to the increased cube of dredging and rock excavation under water, as herein given, and suggested that by raising the

height of the first dam across the river San Juan one metre (3.28 feet), more than two-thirds of the amount of excavation and dredging could be dispensed with ; and also, about 360,000 cubic yards of rock excavation between the lake and the Pacific. This change was not proposed in the original project, because it involved an increase of 3.28 feet in the elevation of the summit level. This would not be justified by the small saving resulting therefrom.

The objections made to this route are: lift locks indispensable to the solution of the problem, length of route, and poor harbors at either end.

A canal without locks, that is, at the level of the ocean, is, no doubt, a great *desideratum*, but its cost, under the most favorable circumstances, would be so great as to place it beyond the possibilty of a successful commercial enterprise. The work, if ever done, will be undertaken by private initiative and private capital, and these are not likely to embark in an undertaking which does not promise sure and liberal returns, however beneficial it may be to the world at large, and however great a monument to mark the present age. Under the circumstances, therefore, recourse must be had to locks, which, if properly constructed and sufficiently supplied with water, will be found less objectionable than has been supposed, The objections to locks are: loss of time in passing through, and liability to accidents. With a moderate number of them, properly constructed, the first objection will be found to be of little consideration, and is surely to be compensated for by the smaller tolls charged in proportion to the reduced cost of the work, as compared to other routes.

In pursuance of the system adopted in the design and computation of this project. of not introducing doubtful elements in the whole or any of its parts, the lift of the locks was fixed at 10.37 feet on the Pacific side, and 10.87 feet between the lake and the Atlantic. All of them have been located so that they will rest on rock or stiff dry clay foundations, and there seems to be no good reason why their lift should not be increased to 15 feet, thereby reducing their number to fifteen.

The ground certainly offers all the facilities that could be desired for the change. The engineers of the Paris Congress fixed the lift at 4 metres (13.12 feet) and the number of locks at seventeen.

General Weitzel, U. S. A., is now constructing a lock on the St. Mary Falls Canal of 525 feet between gates, 80 feet wide and 18 feet lift. Through this lock he proposes to pass a ship in 11 minutes, as follows:

Entering lock	1½ minutes.
Closing gates	1 "
Filling lock	6 "
Opening gates	1 "
Leaving lock	1½ "
Total	11 minutes.

The locks I have designed for the Nicaragua Canal would admit passage to a vessel in about 20 minutes, a time which can be much reduced by enlarging the feeding and draining conduits.

I have the authority of Sir John Hawkshaw for stating that from 15 to 20 minutes would be ample time to pass a lock of the dimensions required for the canal, and the latter time has been adopted as a mean.

As to the liability to accident, it seems to me that, if properly constructed, and intelligently worked, no apprehension should be entertained in that respect. Surely no such objections have been met with in the dry docks in universal use, nor in the large canal locks in operation in this country and others that might be named. There are, on the other hand, certain advantages possessed by a canal with locks over one at the level of the sea; for example, all, or the greater portion of the work can be completed before the water is admitted into the canal; any portion of the canal can be partially or entirely drained into the lower levels to allow an examination or facilitate repairs in the channel or locks; a perfect system of drainage, independent of the canal, can be obtained for the adjacent water sheds, and thus prevent floods from doing injury to the canal. On the Nicaragua line, for instance, all the locks on the Pacific slope, except the lower two, can be drained into the Rio Grande, and similarly some of those on the Atlantic side.

The objection as to the length of the route may be answered by a reference to the statements of distances given before.

It may be seen that the total length of canal navigation is 61.74 miles, and there is no reason why a steamer should not travel in the lake and river with her usual speed at sea.

The estimated time in passing by steamer, from ocean to ocean, is as follows:

62 miles of canal, at 4 miles an hour	15½ hours.
63 miles of river navigation, at 6 miles an hour	10½ "
56½ miles of lake navigation, at 10 miles an hour	5½ "
21 locks, at 20 minutes each	7 "
Total	38½ hours.

Artificial harbors will have to be constructed at either end of the canal. Plans and estimates have been prepared for the same, and they have received the approval of many distinguished engineers, and were accepted by the Paris Congress without criticism. It has been determined by careful observations that the sand bank obstructing the entrance to the harbor of Greytown has been formed by the action of the sea striking the sandy beach at an angle. It is proposed to construct a breakwater or jetty, that, acting as a trap, will intercept the sand moving along the coast from east to west. A channel will then be dredged, under the lee of the jetty, to obtain an entrance to the bay, the latter to be sufficiently deepened by dredging to satisfy the demands of traffic.

At Brito, a breakwater, a pier, and dredging will be required to build a harbor large enough to secure a smooth entrance to the canal, and accommodate a number of vessels. With the lake, only 16 miles from the sea by the canal, possessing all the advantages of an excellent internal harbor capable of accommodating all the fleets of the world, the harbor of Brito need not be large.

Building materials of all kind, such as wood, lime, stone, sand, etc., can be obtained in great abundance, either on the line of the canal, or at a convenient distance from it. With the river San Juan, the two lakes and the river Tipitapa, which can be made navigable for vessels drawing six or eight feet at a small expense, an easy and inexpensive line of communication may be established through almost the whole extent of the country by which men, provisions and materials can be transported to any point along the proposed canal, from Greytown to and through the lake, and from the west coast of the latter to the Pacific, a distance of 16 miles, a railroad can be constructed at a small cost, or the present cart roads can be extended and improved so as to answer the purposes intended.

Sufficient data have not been obtained to determine the annual mean rain-fall of Nicaragua for a number of years ; but, from the observations of Col. Childs in 1851, those of the surveying expeditions in 1872 and 1873, and the records of the College of Granada for the year 1875–1876, we approximately fix at 52 inches on the Pacific slope, and 85 inches on the Atlantic side.

The watershed of Lake Nicaragua is 12 250 square miles, which includes the area of the lake itself, 2 700 square miles. Its outlet, the

river San Juan, has a discharge of 12 453 cubic feet per second when at its lowest stage in the month of May, and at high water the discharge is 20 500 cubic feet per second, these being the flow above the point where the canal leaves the bed of the river, to be located on its left bank, and thence to Greytown. Below the point referred to, the flow is considerably increased by the accession of the waters of the rivers San Carlos, Serapiqui, and other tributaries. Below the Serapiqui the flow is about 22 200 and 55 500 cubic feet per second in the dry and rainy seasons respectively.

The Colorado branch of the river San Juan carries to the sea no less than $\frac{29}{30}$ of the volume of the San Juan, leaving but $\frac{1}{30}$ of the flow to discharge into the harbor of Greytown by the lower San Juan. Many have suggested to close the Colorado by a dam, and thus throw the whole volume of the river into the harbor as a means of scouring it out and keeping its entrance open, but this plan has been thought, after much consideration of the subject, to be impracticable and inefficient.

Earthquakes are rather frequent in Nicaragua, but are only slight shocks that never have done any injury to life or property, nor altered in the least the level of the waters in the lakes, rivers, wells, etc. Works built by the Spaniards over one hundred years ago, such as masonry dams across rivers, fortifications, indigo vats, cisterns and the like, are to-day in an excellent state of preservation.

Conclusion.

From the above statements and considerations it seems to follow—

1st. That however desirable a canal at the level of the sea, partaking of the nature of a strait may be, to better satisfy the demands of trade, its execution, either with or without a tunnel, presents so many difficulties and doubtful elements as to place its probable cost out of the range of a successful commercial enterprise.

2d. That a canal with locks can be so constructed as to satisfy all the requirements of ocean navigation, at a cost within the possibility of a private undertaking, with reasonable expectations of liberal returns and without overtaxing the commerce of the world intended to be benefited thereby.

3d. That while a canal with locks seems to be practicable, *via* both Panama and Nicaragua, the latter route possesses greater facilities for the execution of the work at a reduced estimate of cost based on suffi-

cient information to eliminate unknown elements, which might materially so alter the conditions of the project, as to cause painful disappointment to take the place of long deferred hopes and cheering expectations.

And furthermore, that the geographical position of Nicaragua is more favorable to the United States, whose commerce will contribute more than that of any other nation to the business of the canal, while it will afford as great commercial advantages to foreign nations, as other routes more to the south.

Finally, I would state that, while attempting to confine my remarks upon this interesting subject (upon which volumes have been and may yet be written) to as limited a space as possible, I have treated it more at length than was originally intended, and close with the hope that conciseness, if at all attained, has not been at the sacrifice of clearness in the presentation of the points touched upon.

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TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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DISCUSSION ON PAPER CLXXX.

THE CONSTRUCTION AND MAINTENANCE OF ROADS.*

AT ELEVENTH ANNUAL CONVENTION, JUNE 17TH, 1879, AND AT MEETING OF THE SOCIETY, OCTOBER 1ST, 1879.

By ARTHUR SPIELMAN and CHARLES B. BRUSH, GEORGE D. ANSLEY, A. B. HILL, CHARLES DOUGLAS FOX, E. LAVOINNE, E. B. VAN WINKLE, B. F. MORSE, E. S. CHESBROUGH, E. R. ANDREWS, C. SHALER SMITH, M. MERRIWETHER, J. E. HILGARD, D. E. MCCOMB, F. RINECKER. J. J. R. CROES, JOHN BOGART, C. C. MARTIN AND EDWARD P. NORTH.

A. SPIELMAN AND CHARLES B. BRUSH (SPIELMAN & BRUSH).—Some of the views expressed in Mr. North's paper on "the construction and maintenance of roads," being at variance with the results of the experience of our firm, in the building of 36 000 square yards of Telford roads in 1875 and 1876, and about 25 000 square yards in 1878 and 1879, part of this latter amount being now in the course of construction, we herewith submit the principal facts in relation to these roads, and our conclusions therefrom.

The roads are 80 feet wide between house lines, and are located in the

* Paper CLXXX. By Edward P. North. Vol. VIII, page 95. May, 1879.

northern part of Hudson County, New Jersey; they are built exclusively of trap rock, obtained from and along the line of the road, the stone for the upper courses having been broken by a stone crusher erected on the road by the contractor, the average haul from the crusher not exceeding 2 000 feet. No binding except the screenings and detritus of the stone was allowed in the work, and in each case, the foundation is of rubble, 8 inches deep, and the superstructure of broken stone, 4 inches thick, when compacted.

The roads built under our direction in 1875—1876, may be divided into two classes :

1. Roads by the side of horse railroad tracks.
2. Roads free from horse railroad tracks.

In the first case the width of the roadway from curb to curb is 55 feet, which includes 18 feet of trap block pavement for the tracks, and 5 feet for the gutter.

In the second case the width between the curbs is 40 feet, including 5 feet of block pavement for the gutter.

In both cases the 8-inch foundation was first carefully laid, and great care taken to allow for perfect sub-drainage. Cess-pools, filled in with broken stone, were built at intervals of about 200 feet on both sides of the road, which collect all the water that accumulates in the foundation of the pavement, and these cess-pools are drained by 6-inch stone ware pipes into adjoining receiving basins.

A particular illustration of the importance of this sub-drainage came under our notice. In December, 1875, just after considerable of the foundation had been laid, legal difficulties arose, the work was suddenly stopped, and remained in this unfinished condition until the spring of 1876, receiving in the meantime the wash from the adjoining hill-sides. When the work was recommenced the interstices between the foundation stones of the pavement in many places were filled in with earth. After unsuccessfully attempting to remove this earth, the foundation at these points, as far as they could be ascertained, was taken up and relaid; but as soon as the superstructure of the road was completed we found that, in certain spots, it was always wet, and the surface of the road was continually broken. These spots invariably indicated the points where the foundation was clogged, and the difficulty was only effectually remedied by relaying the foundation, or by building blind drains which carry off the accumulating water.

On the top of the foundation thus prepared, 2-inch stone was then put on, sprinkled, and rolled with a horse roller of 150 pounds per inch run. The one-inch stone and screenings were then spread, sprinkled, and rolled with a steam roller of about 400 pounds per inch run.

After the rolling was partially completed the passing traffic was allowed upon it, and any large stones that came to the surface, as well as all small stones that failed to bind, were raked off and sent back to the crusher to be re-broken for screenings. No water-worn or other rounded stones were allowed in the work. Advantage was taken of every rainfall to roll the surface of the road, because we found that it could be compacted much more thoroughly in wet than in dry weather. Where the pavement was laid on a soft substratum it required nearly double the amount of rolling sufficient for a solid foundation.

The grades of these roads vary from 6½ feet to 8 inches per 100 feet, and the crowns vary from 12 inches to 8 inches.

The roads have now been open for traffic about three years; those along the railroad tracks are used by about 600 wagons per day, the others by about 400 wagons per day. Fully one-half of the traffic on both roads consists of heavy beer wagons from the adjoining breweries, stone trucks and ice carts, ranging in weight from 3 to 6 tons; the balance of the traffic, of ordinary farm wagons, carriages, etc.

No especial care has been taken of the roads, except to see that the gutters and culverts are kept clean. No ruts have ever appeared, and the surface is now smooth and in good condition. In hot weather the roads are somewhat dusty, and in long dry spells they will loosen and break up in spots, where disturbed by the corked shoes of horses drawing very heavy loads, but after the first rain the surface immediately rebinds and again becomes perfectly smooth.

Wind and water are, perhaps, the two greatest enemies of Macadam roads; the wind, by blowing off the slight dust which naturally accumulates on the surface, removes from the road the cushion, which is not only a relief to the traveller, but which also preserves the metal of the road from a vast amount of wear and tear; the water, by flooding the road, has sometimes the same effect as the wind, and if by any means the surface of the road is exposed to a running stream the stones are sure to loosen.

The only effectual remedy we found was to raise the crown of the road sufficiently to shed the water quickly into the gutters, and to keep

the road sprinkled, so that when the winds and floods came the surface would be smooth and compact and not liable to their disintegrating influences.

On the roads by the side of the horse railroad tracks the wear has been about an inch and a half during these three years, while on the roads free from these tracks the wear has been about one inch on the crown and perhaps a half inch on the sides.

The cash cost of the Telford pavement laid under our direction in 1875–76 was ninety cents per square yard.

The stone was broken by a ten-inch "Blake" stone crusher at the rate of about twenty cubic yards in ten hours. The size of the stones as they came from the crusher was: 50 per cent., 2 inches size; 25 per cent., 1½ to 1 inch size; 25 per cent. screenings and pea dust.

The cost of the crusher, engine, boiler, &c., set up complete, was about $2 500.

The cost of working per day, independent of the original cost of the machinery and interest thereon, and also independent of any royalty on the stone, was found by the contractor to be as follows:

Repairs, lubricants, wear and tear on crusher and engine, about..	$6 00
1 engineer, $2.50; 1 feeder, $1.50; 1 screener, $1.50; 5 laborers quarrying and breaking up stones at $1.00.....	10 50
1 team hauling stone.....	5 00
Coal, half ton.....	2 50
Cost of preparing and crushing 20 cubic yards of stone.....	$24 00

Cost of 1 cubic yard, $1.20.

The roads built under our direction in 1878, and now building, are the same in every particular as those built in 1875–76, except that they occupy only 20 feet in width of the crown of the road; the steam roller was not used, and as it is very difficult to obtain an abundant supply of water in the locality, we have to rely on the rainfall for sprinkling, and do all our rolling in wet weather. A horse roller is used of 150 pounds per inch run.

Some 3 000 square yards of these roads were completed one year ago, and have been, since that time, subjected to a daily traffic of about 150 wagons, principally carts, loaded with stone and dirt. The surface of

the pavement is now as nearly perfect as it is possible to imagine that of a Macadamized road to be.

The cash cost of these roads is eighty cents per square yard.

CONCLUSIONS.

A Telford road may be practically divided into two parts.

1. The foundation, which should be uniformly secure, and which should be at the same time a perfect blind drain.

2. The superstructure, which should be a durable, water-tight roof.

If these conditions are complied with—if proper materials are used in the construction of the road, and reasonable attention is given to its maintenance, the result will be as has been claimed, a durable road, unsurpassed for comfort of travel, and one to be preferred to all others for sanitary reasons.

If these conditions are not attended to the road will last but a short time.

The foundation is of the first importance. It should be eight inches in depth. More than this is a waste of material, and a less depth is not sufficiently secure for want of proper bond. It must be laid as close as possible by hand, then the interstices at the top wedged and sledged, until the small stones that compose the superstructure can not work down, and fill the interstices at the bottom of the foundation.

Too much emphasis cannot be given to this part of the work. It is not only essential to perfect sub-drainage; it is equally important in the great saving of the cost of building the road. A loose foundation, which allows the small stones to settle down among the large ones, will require nearly as many again of the small stones before a proper surface can be obtained, hence the cost of the superstructure will be nearly doubled. Of course, if the small stones work down among the large stones, the latter will work up to the surface, and ultimately ruin the road.

An excellent test of a foundation, when the substratum is firm, is to drive a loaded truck--weighing about three tons—over the pavement before any of the upper courses are placed thereon; if the foundation has been properly laid no ruts or other displacement will occur.

As to the size of the foundation stones, we prefer them large rather than small. Nothing is so dangerous as thin slabs. A large stone now and then, say ten inches wide, well bedded, seems to act as an anchor

for the rest, and we have yet to find an instance where the small stones have broken loose from such a foundation stone.

In regard to the superstructure, we are convinced that if the material is crushed trap, any increase over four inches in depth is a waste of material. We found this to be the most expensive portion of the road, the cost of the eight inch foundation being to the cost of the four inch superstructure as one is to two. Four inches will answer all requirements as well as any greater depth, because after the metal has worn down two inches, the road, owing to unequal wear, will need to have a new coating in any event, and the amount saved in the first cost and the interest thereon, by making the superstructure only four inches deep, will keep the road in repair for many years.

In regard to steam rolling, it is often questionable whether it is essential, or even desirable, in the building of Macadamized roads, especially when the road is built of New Jersey trap rock.

The principal action of the steam roller is to crush the stone into the crevices, and the result is, that a crust is quickly formed. On the other hand, the horse roller rattles around and shakes the small stones about, until they are firmly bedded upon the rough but firm foundation and upon each other. No crust is formed, but, on the contrary, a compact homogeneous mass, which result is much more to be desired. Again, the road bed upon which the pavement is laid, often varies very greatly; frequently a rocky bottom adjoins a soft stratum, on one side of the road may be an excavation and the other side a fill. In such a case, a heavy roller is much more likely to disturb the uniformity of the foundation than a lighter one, no matter how great care may have been taken to provide for the emergency.

If it be necessary to finish the surface of the pavement within a week or two, a steam roller must certainly be used, but we believe that rapidly made roads are much less durable than those whose construction extends over a longer period of time.

It required at least three months to finally form the surface of the roads built by us in 1875–76, while on the roads now building, some of the sections have required as much as six months. In the meantime, the surface is kept free from loose and rolling stones, so that there is no brutal pulling through the road metal.

After a road has been slowly compacted in this way, we believe the surface will be found much more durable than that of any rapidly made steam rolled road.

As to "binding," our experience has been that during the construction of the road the less foreign material used the better, unless, perhaps, along the edges of pavement which has only an earth support. In such a case, it is necessary to bind the edges as quickly as possible, in order to prevent the sides of the road from spreading while the surface is forming. After that is accomplished, very little wear comes on the extreme edges of the road.

As an aid in the rapid formation of a fine surface, a little yellow clay placed just below the upper course is almost invaluable, but when the crust is broken the danger is that the surface will soon disintegrate, while if instead of the clay, stone dust is placed between the courses of broken stone, and a top dressing one inch deep of screenings, such as are presented herewith, is spread over the surface and is thoroughly worked into the broken stones, the surface is equally fine and much more durable ; if a spot does loosen here and there, it does not spread and a little moisture quickly rebinds the loosened stones.

Finally, as to the stones for the superstructure, we greatly prefer machine-crushed to hand-broken stones.

1. Because they are much more uniform in size, each having actually passed through a revolving screen.

2. Because the edges of the stones are much sharper and bind better.

3. Because from the machine alone can we obtain the screenings and detritus which we consider so essential for compacting the road and for satisfactory top dressing.

George D. Ansley.—My experience is decidedly in favor of steam rolled Macadam or Telford roads over those formed by horse roller; in fact, I have altogether given up the use of the latter, and employ a 15-ton Aveling & Porter, the result being far greater economy in the end as to outlay, and a decidedly smoother and more permanent surface is obtained.

As to compacting with traffic, I am altogether opposed to it, as being inhuman towards horses and extravagant in the waste of material. I speak of the case when any considerable extent of roadway is to be covered; but in small repairs, or what is technically termed "darning," I first pick up the margins of the depressions, to the depth of an inch or two, and then flush up with stone broken to pass through a 2-inch ring; the edges of the patch are then covered with road grit, obtained at hand and pounded with a rammer. In these repairs it is found that the horses' feet avoid the fresh stone, while the wheels of the vehicles run over the

patch and compact it gradually from the edges to the centre and a very good "mend" is thus made.

In reading over Mr. North's valuable collection of short histories of road making, I was particularly attracted by the mention of ramming, on page 103. There is a short mention of a rammer 8 inches diameter, weighing 70 pounds. Although steam rollers are far more satisfactory than horse rollers, it seems to me that a still further improvement may be made by the more general introduction of the rammer. In all cases of roads, whether Telford or Macadam, or stone paving, or wood paving, the first imperfections are the same; the surface may not be worn away materially, but there are depressions or concavities that hold water. Our block stone pavements get into bad order chiefly through unevenness, and a heavy expense is incurred in repairs, while the hollow parts are found to be hard and well set, and the blocks not worn, perhaps, any more than those forming the better parts of the road. A wooden pavement on one of our streets was condemned for being in hills and hollows; although incidentally there were rotten blocks that broomed and wore away, it was found, on taking it up, that the foundation was uneven, and this notwithstanding that it had been steam-rolled before the blocks were laid on, five years before. All this tells the same tale; the earthy foundation is of unequal density.

Much more attention has been paid to the coating of stone or other material than to the lowest or earth foundation. When a new road is made, the proper form may be given to the earth foundation, and it may be steam-rolled; inequalities then showing themselves may be flushed up and re-rolled, but a roller will bridge over smaller soft places which still remain unseen until the road is completed and heavy traffic put upon it, and then we have saucer-like dips in its surface, to be repaired within a short time after the road is made; and although the specification may require that these repairs shall be done by the contractor, the surface being thus broken, the road is never so good afterwards as it would be if undisturbed.

How the rammer which Mr. North refers to was used is not mentioned; but if by steam power, it might be neither expensive nor slow.

I am inclined to think that the regular stroke of a rammer is the only method of producing equal densities for roads, as well as for other purposes, and that the most important part of road making for its application is the earthy bottom.

After the ramming to equal density, I cannot see that Telford's method is better than Macadam's for general adoption; local circumstances, however, would decide in each case.

After reading through all the various descriptions, and adding my own views from observation and experience, I consider the object to be aimed at is as near as possible, a solid bed of stone. This certainly cannot be accomplished by putting on any earthy matter as binding. Broken stone in thin layers, 3 to 4 inches, chinked with fine chippings or screenings until full, and then watered and rolled with steam roller, will come very near the desideratum. Of course the lower strata may be of stone, less hard than the top. The size of broken stone for the upper part is important. A 2½ inch ring allows stone of considerable size to be mixed with lesser ones, and it is these larger ones that first get loose and move about on the surface. For the surface coating I prefer hand broken stone over machine broken, as the form is generally more cubical and less apt to become disintegrated.

Gravel is much more difficult to reduce to solidity than broken stone; but where there is a large supply, and cheap, it is well to follow the principle before mentioned. The gravel should be screened, and the coarser sort laid on first and then chinked up with the finer. If this is done, and all coarse gravel kept away from the top coating, water and steam rolling will make a good road in almost any case without earthy binding. Earthy matter works into mud, and should be avoided, unless the gravel is so round and movable that nothing else will keept it quiet.

Where old paving is taken up, and it is proposed to put down Macadam, I consider that there is the same necessity for testing the density of the foundation, and rendering it equal by ramming.

A. B. Hill.—In New Haven we have tried several plans in regard to the binding material of the Telford pavement. Using an inch of loam on the crushed stone, with two inches of screenings over that; also using sand instead of the loam; but the best results with us are obtained by using the trap rock screenings alone, spread on in thin layers, sprinkled and thoroughly rolled. This makes a very solid, firm surface, which does not wear into ruts as soon as the pavements top-dressed by the other methods. The roller used is the 15-ton Aveling & Porter.

As the grades in New Haven are generally very light, and it is desirable to secure a uniform, smooth gutter, the latter is made of blue stone, 12 inches wide and not less than 4 inches thick, bedded in sand

next to the curb, closely jointed, well rammed, and, after the pavement is complete, thoroughly grouted.

A space of three feet outside the gutter stone, between the rails of the horse railroad tracks, and for three or four feet outside the rails, is laid with stone blocks.

The Telford pavement is 16 inches thick at the centre and 14 at the the sides, made up of 4 courses of trap rock ; the first or bottom course 7 inches thick at the centre and 5 inches at the sides ; the stones of the size and placed as usually specified for Telford foundation ; the second course, 3 inches thick, of stone simply raked out and sorted at the foot of the trap dikes (not "broken" or "crushed"), varying in largest dimensions from 1 inch to 4 inches, spread on the first course and rolled until solid ; the third course, 4 inches thick of "crushed" stone, also rolled ; the fourth course, or top-dressing, about 2 inches thick of screenings, spread on in three layers, each layer sprinkled and thoroughly rolled in.

The average cost of the Telford pavement in New Haven, including the Belgian blocks, blue stone gutters, crosswalks, inspecting, rolling, &c., was, for 1876, $1.18 per square yard.

" 1877, 1.05 " "
" 1878, 1.15 " "

Charles Douglas Fox, of London (through the Secretary).—There can be no doubt that the present system of consolidation of the Macadam is very imperfect, even when a steam roller is employed. I am of opinion that a better result would be attained if a really good steam rammer or stamper could be devised. At present the roller leaves the upper stones in a very loose and disintegrated condition. Our Victoria Embankment, upon which no expense was spared during construction, seems to be in constant need of repairs, and this although steam rollers were employed.

A really good pavement for cities remains to be discovered, which would fulfill properly the economical and sanitary conditions, and at the same time be noiseless and safe.

Asphalte soon wears out, and is very dangerous when damp, but not very wet.

Wood pavement is difficult to clean, and allows the substratum to become saturated.

E. Lavoinne, Engineer des Ponts et Chaussées, France (through the

Secretary).—The criticism of Mr. North upon the Macadam roads in the City of Paris, is to the effect that owing to the method of compacting, sufficient stability is not given to the stones to resist the traffic. Mr. Malo is quoted as sustaining this criticism. Even if the bad results in Macadam pavement in Paris were something like what Mr. Malo describes in his rather sweeping remarks, the fair inference would be, it seems to me, that the system of construction was not the best in that location on account of the heavy traffic.

Macadam roads when introduced in Paris to replace the former pavements were considered by many engineers as a blunder on account of the cost of their maintenance and other peculiarities. It is certain that no Macadam road, even if constructed under the best conditions, could stand the enormous traffic existing in many streets, which is not occasional as Mr. North states is the case for some of the Boulevards of New York, but continuous and daily for most of them.

As regards the construction of roads, the illustration of what Mr. North calls the French system, such as he saw applied in the repairs of some streets in Paris, hardly gives an exact idea of the standard system adopted by many French Engineers. They generally consider that in a perfect Macadam all stones should bear directly against one another by faces as large as possible, not by edges, and that the interstices, previously reduced to a minimum by rolling should be filled afterwards with a binding which cannot be affected by atmospheric influence nor give access to moisture. Thus far they agree with Mr. North—but they disagree with him as to what is the best binding.

Instead of screenings or very small stones with the addition of dust and water, they prefer to use sand with a small quantity of chalky dust employed when compacting is at an end. They consider, contrary to Mr. North's theory, that when the stones, whose sizes vary between 1½ and 2½ inches, have been thoroughly packed together by rolling before any addition of binding, so that they move no more under the roller, and a beginning of crushing takes place, then an addition of smaller stones is useless for stability ; if very small stones like screenings were then added, they would be crushed and produce an excess of dust injurious to general stability. Sand, injected by thorough watering between the stones is not liable to that objection, since, filling all the interstices it tends to equalize the pressures between the stones. The addition of chalky dust diluted by water, at the end of the operation, fills the inter-

stices between the grains of sand making with it a sort of mortar and coating for the surface. In my own experience the best results followed this method ; the consolidation of the Macadam was very satisfactory at the end, rolling not being spared before the addition of binding. Loose stones occurred only at a few points.

It may be that the roads examined by Mr. North, in Paris, were constructed in too thick layers and too hastily to permit the stones, prior to any addition of binding, to have the required stability, much rolling being necessary for this result. This may be the reason why loose stones were seen. If the stones have not been packed and wedged previously by thorough rolling, we cannot expect binding to make them immediately compact.

The system mentioned as used in New York (St. Nicholas Avenue), in which stones of from 1 to 1½ inches are employed for the top course will, no doubt, do for light travel (light, not heavy carriages); but such pavement would very likely be destroyed by a heavy traffic, as the small stones would then be rapidly ground and disintegrated. From my own experience and that of many engineers in France, I am fully satisfied that the capital difference between the roads in the old Macadam style without rolling, and those that are rolled, whether with steam or horse power, is the degree of internal wear ; as the grinding of the stones by their reciprocal friction or internal disintegration is much more rapid under heavy traffic with the former than the latter. In the first case the proportion of disintegrated material, detritus, to the stone is generally large after a short time ; very small in the second if proper care has been given to the work.

Evidently much more consideration should be given to the internal wearing which is of serious consequence as to cost of maintenance than to the incomplete consolidation of the road immediately after rolling which could be remedied by more rolling or made up afterward by the traffic itself and by removing the excess of binding material by sweeping.

In conclusion it is suggested that for a fair comparison between the different systems of constructing the roads, there should be taken into account, both the quantity and quality of the traffic, and also the cost of maintenance under the same conditions for a fixed period. Conclusions might be different if full consideration were given to these points.

E. B. Van Winkle.—I would say that I am familiar with the roads Mr. North has been constructing for the past few years, that is, with their

present condition, and should like to ask Mr. North if their present condition bears any relation to the amount of rolling he put upon them ; for instance, the Southern Boulevard, which I now consider to be the best of these roads, and the one that carries the greatest traffic, did that receive the greatest amount of rolling ?

E. P. North.—The Southern Boulevard received 0.859 ton miles per square yard, or 5.177 ton miles per cubic yard, which is more rolling than any other road constructed by me had, and more than any road known to me has had applied to it.

The road has stood the wear very well, though part of it is exposed to a very constant breeze from the Sound, which deprives it of the protection that a layer of dust would afford.

The teams on it were counted from 8 a. m. to 5 p. m., and averaged about 300, from four horse teams, with six or seven tons to the load, to buggies.

E. B. Van Winkle.—Next to the Southern Boulevard I should place the streets constructed by Mr. North in the following order as to degree of excellence, always judging by their present condition :

1st. One Hundred and Thirty-eighth street ; 2d. One Hundred and Sixty-seventh street ; and last, Mott avenue. Please, if possible, state which of these received the greatest amount of rolling, and if there were any differences in the quality and size of the metal and the material used for binding.

E. P. North.—One Hundred and Thirty-eighth street which has two courses of broken stone, each about 6 inches deep before rolling, received less rolling than the Southern Boulevard ; the surface is satisfactory except in one place, where the bottom was bad and mud worked up through the metal where there are some loose stones. One Hundred and Sixty-seventh street is on a heavy grade, part being at the rate of $11\frac{2}{10}$ feet per 100, and the rest with 8 per 100 for a maximum. The first was rolled with both horse and steam rollers. The steam roller ascending by an easier grade. Some clay hardpan was used here in connection with the screenings, both to increase the adhesion of the roller wheels and facilitate the compacting of the road bed. The roller, a 15-ton Aveling & Porter, old pattern, ascended the grade after the application of the hardpan. On the lighter grades nothing but screenings was used for binding and the rolling was done entirely by steam. This part of the wheelway wears much better than that portion where hardpan was

used. No reliable account was kept of the amount of rolling this street received.

The circumstances under which the wheelway on Mott avenue was constructed are fully detailed in Transactions Vol. VIII, page 110 (May, 1879). On account of its treacherous bottom it probably received less rolling per square yard than any other road, though it was impossible to keep accounts of the amount of rolling done.

All of these streets are Macadamized with two-inch trap and clean trap screenings, excepting that portion of One Hundred and Sixty-seventh street, mentioned above.

B. F. Morse :—The paving of the Cleveland Viaduct, west of the river, over the arches, is laid with New York Medina sandstone ; the roadway is 42 feet between curbstones, with a double track street railroad in the centre.

The ballast used was of the best quality of bank gravel spread in layers of about five inches in depth. Each layer was sprinkled with water and rolled. The last layer or that directly underneath the stone, was about two inches deep, and was left without sprinkling or rolling to receive the bed of the paving stones. The surface of the ballasting was finished to the true crown of the roadway.

The pavement is laid with blocks, dressed nearly parallel on top and bottom, sides and ends, laid in courses transversely across the roadway. The courses were from three to four inches thick, and from six to seven inches in depth, and the stone from seven to twelve inches in length. The stones were set close together, so that no joint was more than one-half inch open for at least two and one-half inches down from the top surface.

No gravel or sand was placed between or on top of the pavement while it was being laid. After the stones had been set in place in sections of fifty to one hundred feet in length of the street a light top dressing of gravel or sand was spread over the surface and swept into the joints with a steel splint broom. The pavement was then thoroughly sprinkled or flooded with water. Then the pavement was thoroughly rammed two or more times with a paver's rammer weighing about ninety pounds ; then the pavement was again washed or flooded and allowed to dry off.

The joints were then filled to a depth of three to five inches with a concrete composed of Trinidad bitumen and coal-tar cement, distilled at a

temperature of not less than 600 degrees Fahrenheit, and mixed in proper proportion, so as not to soften or become brittle under heat or cold, and was poured into the joints of the pavement at a temperature of not less than 300 degrees, and then the whole surface was covered with one-half inch of fine gravel or sand, which completed the work.

The pavement on the fixed iron spans was laid in the following manner: Strips of oak plank varying in thickness from one and a half to three inches were secured to the iron floor beams, running longitudinally, to give the proper crown to the roadway. On top of these longitudinal floor beams was laid a layer of two and one-half-inch plank, joints well broken and spiked down. On top of this layer of plank there was laid two thicknesses of tarred roofing felt, or paper laid in hot roofing cement, and the whole covered with one-fourth of an inch of plastic pitch, and over this was laid a layer of inch boards or sheathings, breaking joints with the plank underneath, and thoroughly spiked down.

The paving is what is usually called "Nicholson," and consists of blocks four inches long and three inches thick laid upon and in rows across the roadway with a three-fourth-inch strip, one and one-half inches in depth between the rows of blocks, and nailed to the flooring, the blocks breaking joints at least two inches with adjoining row. The space between the rows of blocks was then filled with concrete, composed of one part of hot undistilled gas tar to two parts of pitch, mixed with clean lake sand and fine gravel, applied hot and driven into the joints with an iron blade and heavy rammer, until the spaces were even full. The whole surface of the paving and gutters was then coated with a top dressing of coal tar, pitch, and fine gravel, rolled thoroughly with a heavy hand-roller. The best quality of seasoned white oak was used for all the wood parts of the pavement and plank floors.

E. S. Chesbrough.—I cannot state the average wear of wood pavements; I can only state that it differs very much with regard to different kinds and in different localities. You can easily see that very much depends upon the faithfulness of doing the work and the material used.

In some cases in Chicago wooden pavements have lasted ten years, and even longer; and in others they have become very rough and uneven in three or four years. I am not able to give the precise average, but of course a great deal depends upon the traffic. In the river tunnels the wooden pavements have worn out in less than two years, and where the wheels were confined very much to the same tracks they make ruts in

a short time. In other cases, where the streets are broad and clear, and the traffic is spread over a large space, they have lasted a long time; in some cases ten years. It is impossible to give the rule in regard to that unless you take into account various circumstances.

Edward R. Andrews.—I would like to ask Mr. Chesbrough whether a Chicago there is any very perceptible wear in wooden pavements until decay sets in?

Edward S. Chesbrough.—Decidedly; I have seen some worn down more than two inches without any apparent decay.

Edward R. Andrews.—Mr. North states that a well made Macadam road constructed with trap rock is, after an earth road, the pleasantest and safest known. But trap rock or other really good materials for making Macadam roads are not available everywhere, and at best Macadam roads are only adapted for pleasure travel in parks or suburban towns, where they can be constantly watered and never allowed to get out of repair. Macadam is not adapted for general use in cities. Under heavy traffic, the surface is constantly ground into powder, which rises in dust in the summer, and they are very muddy in the winter. Even in Paris, where the maintenance is most thorough, the streets being continually watered in summer in the manner described by Mr. North, and frequently washed after a day of unusual wear, and scraped by a large army of cantonniers, yet, after heavy rains, the mud is frequently nearly ankle deep, and in very hot weather during the intervals of watering, or in frosty weather, the air is filled with most penetrating dust. Mr. Flad describes the same state of things in St. Louis; and, in Boston, when, in winter, there is no snow to cover the ground, and on account of the cold, the streets cannot be watered, the dust is intolerable; and in summer where, for economy's sake, watering is neglected, a large part of the material, with which the roads are made is blown into the sea.

The Compressed Ashphalte, so common in London and Paris, when constructed as thoroughly as it is in those cities, and as that on Fifth Avenue in front of the Hotel Brunswick has been, is a most excellent pavement, but it also demands the most careful maintenance. No dirt should be allowed to accumulate upon it. In frosty or in damp weather, coarse sand or fine gravel should be spread over the surface to give a good footing for horses. This is done abroad, and then it is not slippery; it is very quiet, and in fact has almost all the qualities needed in a perfect pavement, but it can only be laid on levels, and is expensive.

Stone Block Pavements are in many parts of the country the cheapest, and possibly may be the best where the traffic is very heavy, but it is emphatically the worst pavement for streets of residences or wherever quiet is desirable; and there is no question but that if the incessant din from the rattling of omnibuses, heavy teams, milk wagons, &c., from which one suffers in large cities paved with stone blocks, could be dispensed with by adopting a quiet pavement, the length of life of citizens would be increased and the general health improved. Such would have been the case long ago in New York, had it not been that the wooden pavements laid during the "Tweed" days were such evident jobs. In London, wooden pavements give entire satisfaction. The earliest were not quite successful, but the defects in construction have been remedied, and now broad areas of heavily worked streets previously paved with stone are being laid with wooden blocks, which are found to wear satisfactorily.

In the West, where stone for pavements cannot be had, wooden blocks are largely used; but, as wood is cheap and can be replaced without much expense, no sound principles are followed in their construction. In the Eastern States, no one will allow that a wooden pavement can be good except when newly laid, when all agree that it is delightful. There seems to be an unwillingness, even among engineers, to give the subject the attention it deserves. All agree that stone pavements are a curse, and that it would be a blessing if a good substitute could be found, but because wooden pavements, as they have been made here, have not been a success, condemn them as a class.

Mr. North has stated what has been the general practice in laying wooden pavements in this country. Many methods have been tried, but they have almost without exception been "laid with *green* or wet blocks, more or less thoroughly dipped in tar, on a bed of sand, not always well rammed, with or without the interposition of a tarred pine board, with transverse joints from one to one and a half inches wide filled with gravel and coal tar," and I might add, the whole done in a most unworkmanlike manner.

The results are what might have been expected. The careless manner in which the joints have been filled, has left many channels open for the admission of water, which undermines the sand foundation, so that there is an uneven subsidence under the passing wheels, and holes, small at first, but daily growing larger, appear, so that the surface is

soon destroyed. The result is but little better when tarred boards are laid under the blocks. This practice of tarring wet, sappy boards and blocks seems to be an invention to make them decay as soon as possible. It closes up the cells of the wood, so that the moisture cannot escape; fermentation immediately follows, which quickly destroys the strength of the fibres and reduces them to punk. A pavement, constructed in this manner, would fail of course. Thoroughly seasoned wood might be benefitted by the tarring process, but green wood never.

Observe how differently wooden pavements are constructed in London. Mr. North describes several methods, either of which is vastly superior to any of the patented systems used here. A rigid foundation of bituminous or cement concrete is universal. This costs more than sand, but it is permanent, and will prevent the blocks from sinking under the wheels. English engineers, in discussing pavements, call the foundation the true pavement, the blocks being the wearing surface only. The "Henson" pavement, with some modifications, strongly recommends itself to my mind as the best for this country. Instead of a layer of tarred paper on the concrete, I would use a thin layer of pitch, with oil enough in it to make it permanently slightly plastic, setting the blocks upon it while hot and soft, using the strips of tarred felt between the rows, and driving the blocks together as described by Mr. North. The tarred felt would make a very close joint. Then pour melted pitch over the whole surface, taking care to fill every crevice, and upon this spread fine sharp gravel, which will work into the ends of the blocks and form a surface resembling macadam, and afford a far better footing than wide spaces between the rows, which serve as receptacles for mud and dust. It is easy to keep this pavement clean. No water can penetrate it, so that it will not be injured by frost. The blocks themselves, if creosoted, will not absorb water, and if laid without spaces between the blocks, the drainage will be surface drainage solely, which is of the first importance.

But the pavement would be short-lived, if *green* and wet blocks are used. It is not practicable to use, as Mr. North says is the case in London, "wood better seasoned than the pine generally used by house carpenters in this country." Seasoned wood cannot be obtained in sufficient quantities here. But, what is far better, it can be preserved from decay. I have no faith in any method of wood preservation for paving blocks, which does not exclude water. The blocks are so short, that any soluble

preparation is quickly washed out of them, and, if not made waterproof, they are certain to absorb the seeds of destruction from the filth in the streets. The blocks should be well saturated with creosote oil, whose chemical constituents act preservatively upon the fibres of the wood, by coagulating the albumen of the sap, while the fatty matters act mechanically in obstructing the pores of the wood and keep the water out. At the same time, as oil cannot be injected into wood full of moisture, the thorough artificial seasoning, which forms a part of the process of creosoting as carried on in this country, is as useful to the timber as any of the metallic salt processes.

By thoroughly creosoting the blocks, expansion and consequent throwing out of the blocks is prevented. They will not shrink or expand. The wood is also rendered homogeneous; the sap wood becoming as durable as heart wood. Looking to sanitary considerations, the creosoted wooden pavement is perfect. The carbolic acid contained in the oil is a powerful disinfectant, and as the pavement described will not absorb any deleterious substance from the surface, it has only to be kept clean to maintain the best sanitary condition. This is far from being the case with wooden pavements laid on the American plan. They soon become a mass of decaying vegetable matter, and, as their powers of absorption increase with their disintegration, they become filled with corruptible matter absorbed from the filth of the street, and as their surface becomes filled with holes, it is absolutely impossible to keep them properly clean.

A good wooden pavement is also an inexpensive one. The cost, including a cement concrete foundation, 6 inches deep, would not exceed $3.00 per square yard. The system of maintenance adopted in London, of making it a part of the contract of construction, would insure good workmanship in laying the pavement, and a good permanent roadway afterwards. It would not be difficult to find responsible and honest contractors willing to take such a contract at a fair price.

In considering this subject, one should not overlook the statistics of accidents gathered in London by Col. Haywood,* which show that a London horse will travel on granite 132 miles, on asphalte 191, and on wood 446 miles, before an accident occurs.

The actual wear of wooden blocks is very slight, as long as the fibres of the wood are sound. Mr. North states that it is $\frac{1}{8}$ of an inch per

* See full reports in the library of the Society.

annum in the streets in London, with the heaviest traffic. Mr. Geo. Frederick Deacon, Member Inst. C. E., in a paper read before the Inst. of C. E., states that, in Great Howard street, Liverpool, which is a shop street, with a traffic consisting chiefly of carriages, amounting to about 94,000 tons per annum per yard in width, the pavement was worn to the extent of $\frac{5}{8}$ of an inch in four years. This would give a life of nearly twenty years before the blocks would be reduced from 6 inches to a thickness of 3 inches, which is still sufficient to maintain the blocks in place.

In Oxford street, in London, where the traffic is equal to 300 tons per foot per day, the amount of wear has been found to be from $\frac{1}{16}$ to $\frac{1}{8}$ inch during three and a half years. This street is laid with the Henson pavement. This slight wear is largely due to the fact that the ends of the fibres do not broom, and thus retain their original strength.

C. Shaler Smith.—I merely wish to ask Mr. Andrews—speaking of the foundations of wooden pavements, if he is aware of any pavement being laid as upon the Cleveland Viaduct, that is, Nicholson pavement upon an iron foundation ?

E. R. Andrews.—I am not aware of any except the Broadway Bridge in South Boston, where it was necessary to have a light pavement. A bituminous concrete about two inches thick was spread on the top sheeting and allowed to become solid ; then a thin coating of hot tar spread evenly, and creosoted spruce blocks, injected at my works with 12 lbs. of oil per cubic foot laid in rows $\frac{1}{2}$ inch apart, and the insterstices filled with pitch and the surface spread with gravel.

G. Bouscaren.—Can you give the cost of creosoting ?

E. R. Andrews.—$12.00 to $16.00 per thousand feet, board measure.

G. Bouscaren.—Can spruce be treated well ?

E. R. Andrews.—Spruce does not absorb oil readily on account of the compact character of its fibres, yet it will take in a gallon of oil per cubic foot ; hemlock, pine, both white and yellow, and porous oak, are more absorbent. Wood which is the most destructible, because it absorbs water readily, is really the best for creosoting, as, for instance, the gums and cottonwood.

G. Bouscaren.—Have you any special rule for determining the amount of carbolic acid in the oil ?

E. R. Andrews.—I have not taken any pains to ascertain. The quantity depends upon the character of the coal from which the gas

was made, varying from 5 to 10 per cent. It has been ascertained, however, through careful experiments by a Belgian chemist, that the wood-preserving qualities of creosote oil are due rather to the water-proofing imparted to the wood by the hydro-carbons contained in it than by the carbolic acid. The latter is very volatile, and were it not retained by the gummy, resinous oil would quickly escape into the air. In England no reference is made to the quantity of carbolic acid contained in dead-oil to be used in the specifications for contract work. Carefully conducted experiments of my own with pieces of yellow pine, 8″ x 8″ and 9 feet long have shown, that six months after treatment they did not absorb any water during a soaking of 48 hours under water.

M. Merriwether.—We made in Memphis, in 1867, what has proved to us a very costly experiment in wooden pavements. We laid there in that year and the succeeding spring, some 225 000 square yards of what is known as Nicholson pavement. The streets on which this was laid rise six inches from the side to the centre of the street. Two inches to two and a half of sand were laid down, and that covered over with an inch board longitudinally. Those boards were immersed in hot coal-tar. After that were laid cypress blocks eight to twelve inches long, with a thickness of three inches, with a cleat between them, tacked to them. About one-half of that kind were immersed in boiling tar. According to the contract it was to be red cypress wood, which is very durable above-ground, and of more than ordinary durability underground, and is found to last better than ordinary oak ; but the sap portion of that wood is very perishable, rotting within one or two years if exposed above-ground. The heart will last twenty-five years, or so, in fences. I mention this to show the durability of the material. Most of that was entirely covered with boiling coal-tar and small gravel, and the interstices filled with sand, making a beautiful pavement for about three or four years. Some portions of it, however, began to show decay in three years, where the sap of the block was put in. The contractor got in a good many sap blocks, and as soon as they began to decay the adjacent blocks were loosened, so at the end of about five years it was in many places impassable, and some blocks were entirely destroyed. The remnants of that wooden pavement of 1867 and 1868, are now there. The pavement cost us $3.89 per square yard. I am satisfied had the blocks all been heart cyprus it would have been good for perhaps ten years. We have portions of the pavement now where the heart of the cypress was used, where there is no sur-

face wear perceivable. However, we are satisfied with that experiment, and I do not think we will ever put down another square yard of wooden pavement of any sort. We are now making arrangements to pave with granite.

E. R. Andrews.—It seems to me very clear that the reason why the cypress pavement did not last was because the blocks were dipped in tar. It is not at all probable that these blocks were perfectly seasoned, because seasoned lumber cannot be found in this country for paving purposes, hence the sap enclosed within the wood by the tar soon fermented and the fibres rapidly decayed. If the blocks had been laid without being dipped in tar I think you would have had a very fair pavement now.

I would like to ask as to the condition of a pavement in Washington called the Flannigan pavement, with cypress blocks sawed from round sticks and laid promiscuously, large and small together, the spaces being filled with pitch. I have understood that that pavement has stood well.

J. E. Hilgard.—That pavement has done the best of any in the city. It was tried as an experiment on Third street, near the railway.

The city of Washington has made very extensive experiments in the matter of wooden pavements. Nothing was done to preserve the blocks. They were hemlock; none of it has lain in tolerable condition over four years; much of it had become intolerable even before that time. I think the work was badly done from there not being proper supervision. An immense amount of work was undertaken to be done within a limited time. It was the most disgraceful failure of wooden pavements ever known, and it has been a case of unprecedented decay. None of the streets were in a fit condition to travel over after four years; most of them have been replaced by concrete pavements. With us the experiment has been a very expensive one. Climate may have had something to do with it, for it is very warm in summer and we have very frequent showers, but certainly the decay was unusually rapid.

E. R. Andrews.—In 1869, Columbus avenue, in Boston, was paved with wood; every one who had any patent pavement was allowed to put down a piece; one section was laid with creosoted blocks, but very imperfectly prepared. All the pavements were taken up and the street repaved with the Trinidad bitumen in 1877; but a small delta of the creosoted pavement was left, which is still sound and in good condition.

M. Merriwether.—I did not mention that about one-half of the pavement of which I spoke, was laid with planks dipped in boiling tar, and after making about one-half of it the very difficulty suggested by Mr. Andrews arose, and we ceased to immerse the blocks, upon the theory that if the under side was covered with tar it would cost more, so they stopped that process and laid the balance in the other way, and after the planks were down they covered the surface simply with coal tar, upon the theory that the bottom of the planks, not being concealed, the acid would go down; but we did not discover that it made any perceptible difference. It would probably have been satisfactory if the blocks had been heart wood, but the sap of the blocks decaying, led to their destruction by the wheels passing over it. It was an utter impossibility to have seasoned wood for such an extent of pavement—some 225 000 square yards, laid at once. The wood was not in the market, and no one could afford to keep such a stock on hand. The result was that the wood was brought directly from the mills and put down within two or three months from the time it was taken from the stump. I do not think any process short of thorough seasoning, or some process of drying quickly by steam, would do any good. We found it impossible to get the heart cypress entirely, and the sap wood would decay in two or three years.

The blocks covered the surface and prevented the water passing down, but it may have passed on the side. They merely covered the surface with tar, and some little water might find its way down the side of the block. The spaces between the blocks were thoroughly rammed with small gravel, with sand with it, and the surface covered with coal tar.

C. Shaler Smith.—I have recently made some experiments for the St. Louis Bridge, which illustrate in a marked degree the action of these preservatives depending on carbolic acid for their antiseptic value. Finding the wooden stringers of this structure beginning to rot at the ends and other points of support, while the remainder of each stick continued sound and untouched by decay, I tried to arrest the rotting by the injection of creosote containing ten per cent. of carbolic acid into all these timbers which showed signs of decomposing fibre. The effect was remarkable. Sound wood was unharmed, but where decay had already commenced the acid seized upon the wood and converted all parts affected by rot into a brown cinder, in many cases absolutely destroying

the bearing value of the stick. The experiment was extensively and exhaustively tried, and I am satisfied that while creosote is excellent when properly applied to perfectly sound lumber, it will not arrest decay when once started, and in many cases will destroy all the unsound parts of a stick.

And also, that in the use of creosote, the proper proportion of carbolic acid is a very important element, and should be fixed by specification whenever this system of treatment is used. I have likewise continued experimenting on other methods of preserving wood, three of which have given good results.

The first is the "Thilmany, old process." This consists in impregnating the wood with sulphate of copper, and subsequently with the chloride of barium. The chemical action of the two salts fills the pores of the wood with the preservative chloride of copper, mechanically fixed in position by the insoluble salt, sulphate of baryta.

The second is the "Thilmany, new process."* Here the first impregnation is sulphate of zinc, the second chloride of barium, and the resulting salts, chloride of zinc fixed as before by sulphate of baryta.

The third is known as the tan-zinc process. The first impregnation is with chloride of zinc dissolved in a solution containing 2½ per cent. of glue. This is followed by an injection of a tannin solution which precipitates the glue, forming tannate of gelatine, a perfectly insoluble compound, and which fixes the chloride of zinc so thoroughly that it cannot be extracted either by boiling or steaming. I am not now prepared to state which of the three processes is the best, as our experiments are still going on. It may be safely asserted, however, that no system of treatment depending on a soluble salt, as in the Burnett or Boucherie processes, is of any value unless the salt is fixed in the wood by a subsequent injection which will fill the pores with an insoluble substance. I have procured specimens from various Burnettized bridges, and the analysis has shown in every case that the zinc had been entirely washed out of the wood. In treating wood by either the creosote or metallic salt systems the antiseptic injection is virtually worthless unless the wood has been previously deprived of its sap. In doing this the following rules should be rigidly observed.

First.—The steam bath should not exceed 5 pounds pressure, or 240° F. in temperature, and the lumber should remain in the bath for not less

* For specifications of this process, see Appendix No. 6.

than 90 minutes for sticks under ten feet in length, and 9 minutes additional for every additional foot of length.

Next.—The steam bath should be followed by an exposure to a vacuum of not less than 11 pounds pressure for 40 minutes for sticks less than 10 feet in length, and 6 minutes more for each additional foot, after the vacuum is reached.

Last.—The preservative injection should be run in while the vacuum is still on, and after the cylinder is filled the injection pressure should be brought up gradually to not less than 100 pounds. The time for its continuance will vary with the wood used and the length of the stick.

By the observance of these rules in treatment and the selection of thoroughly sound lumber, it is in my opinion perfectly practicable to produce a good wooden paving block, which, when properly laid, will make a clean and lasting pavement. Treated gum blocks placed in the testing machine at the St. Louis Water Works stood the passage of 95,000 wheels with a wear of only one-eighth of an inch. The wheels of testing machine were loaded to 2,000 pounds per wheel or 800 pounds per inch of tire width.

It is hardly necessary to reiterate, however, that no system of treatment, however good, will arrest decay, convert unsound blocks into sound ones, or render blocks cut from dead trees fit material for a pavement.

Edward R. Andrews : I do not wish to advocate the use of decayed timber, or to intimate that by the process of creosoting, wood which has lost its quality by reason of decay can be restored to its original strength; but if partially decayed timber be creosoted the process of decay is arrested, and there may be cases where it will be advisable to creosote it, and thus save for future usefulness timber which would otherwise be valueless.

As an instance of such an experiment, I quote from the *Journal of the Society of Arts*, London, June 1st, 1860, containing a paper by G. R. Burnell, entitled "On Building Woods, the Causes of their Decay, and "the Means of Preventing it," and a discussion thereon by the members of the society, during which Mr. John Bethell made the following statement (see page 565).

" That in timber where decay had commenced it had been stopped by " the injection of creosote. He could confirm that fact by stating that " about twelve years ago many thousand sleepers were packed upon the

"Lancashire & Yorkshire Railway some time before being used. When "they were about to be used they were found to be more or less decayed, "and it was a question whether the whole should not be sold for fire-"wood, when it was determined to submit the sleepers to the process of "creosoting. After those sleepers had been down for ten years it was "found that not only had the decay been arrested, but the sleepers were "as good as if they had been sound, new timber."

I do not quite approve of General Smith's specifications for the treatment of timber. Unless he has positive proof to the contrary, I should doubt whether large-sized timber can be properly dessicated in ninety minutes. In my own experience I find that the time required is greater with large timber than with small, and in proportion to its square rather than its length. Wood is a slow conductor of heat, and a 12″ by 12″ stick cannot be heated through to a point of vaporization in ninety minutes, and the moisture cannot be withdrawn until it is vaporized. Moreover, it will require a vacuum of 20 to 25 inches during several hours to withdraw the vapor, so that danger of decay from moisture within the wood shall be removed. If this is not accomplished before injection with creosote, the effect will be to close up within the wood fermentable substances. Thorough injection cannot be effected. The incompressible water will not permit the oil to permeate those portions of the wood where it exists.

Engineers should give time enough to do good work. In the practice abroad and in this country, where creosoting is done intelligently, the work is never hurried. Large piles and square timber cannot be properly dessicated and creosoted in less than from 20 to 24 hours. Such work costs more money, but is cheapest in the end. Paving blocks can be treated much more rapidly. During the infancy of creosoting in this country great care should be taken to secure thorough work in order to obtain for such timber the longevity attained in Europe and the confidence of consumers.

David E. McComb—I shall confine my remarks to granite and bituminous pavements as laid in the cities of Washington and Georgetown, D. C.

The standard stone pavement has a base of six inches of hydraulic concrete, upon which is spread three inches of sand, in which the granite blocks, measuring eight inches by four inches by six inches in depth, average, are bedded with close joints, which joints are filled with

screened gravel, pea size, heated to a temperature of 400° F. The blocks are then brought to a solid bearing by the use of the ordinary rammers, after which the joints are filled with coal tar refined to 400° F., which removes the light oils, water, &c., yet retains the heavy oils, "cut back," which is the result of a mixture of the residuum of the destructive distillation of coal tar, with still bottoms, being carefully guarded against. After the joints have been filled with the tar as before described, fine heated sand or perfectly pulverized limestone is spread over the surface, which completes the pavement. In situations where the sub-foundation is solid and unyielding the concrete base is dispensed with, six inches of gravel compressed by a heavy steam roller being substituted in its stead.

All the different kinds of tar pavements have been laid and tested in Washington, and our experience is that they are not economical, requiring too extensive repairs and too frequent renewals.

The only two pavements that have given any reasonable degree of satisfaction are those having a mixture of Trinidad bitumen and coal tar refined to 400° F. in approximately equal proportions as the cementing medium of the sand, limestone or other ingredients forming the body of the wearing surface. Such a top coating is good for about seven years, requiring, however, watching and small repairs during this time, after which it seems impossible to patch it successfully.

There have been laid six squares of Neuchatel under two different contracts, the first in 1872, the latter in 1876. That laid in 1872 on I street has stood the test of time and limited travel very well and is in fair condition now. That laid in 1876 on Pennsylvania avenue is in very poor condition, and requires extensive repairs, This class of pavement possesses one fatal objection, viz., its extreme hardness, as a consequence of which, when the surface is covered with a film of water it is only by the exercise of great care that horses can travel upon it without slipping and falling oftentimes, especially in turning corners.

The pavement of this general class that has given the most satisfaction has for its foundation a depth of six to eight inches of hydraulic concrete, upon which is spread a coat of asphalt mastic half inch thick, which is intended to give an uniform surface to compress the top coat upon. This cushion coat, as it is termed, is composed of 62 parts of fine sand, 15½ parts of pulverized carbonate of lime, and 22½ parts of asphaltic cement; all the compression given to this coat is that due to

rolling with a hand roller weighing about ten pounds per inch run. The top coat or wearing surface is composed of 65 parts of fine sand, 16 parts of pulverized limestone and 19 parts of asphaltic cement. The sand is required to contain not more than five per cent. of clay, and to be a little finer than would be usually accepted for use in making mortar; the asphaltic cement is composed of refined Trinidad asphalt and refined petroleum still bottoms, or paraffine oil in the proportion of 100 pounds of the former to 19 pounds of the latter. The pulverized carbonate of lime is mixed, when cold, with sand heated to 300° F., which mixture is then mixed with the asphaltic cement, heated also to 300° F., and a thorough incorporation is effected in a twin pug mill, after which the material is carried in carts, having an arrangement to keep it hot to the work, and is spread upon the cushion coat with rakes, and having a thickness of $2\frac{8}{10}$ inches. It is then rolled with the hand rollers before referred to, the jointings at the curb being tamped with the pilon described by Mr. North, which is heated to a temperature of 500–250 F., the test of its being too hot is that it scorches a white pine plank, on hand for the purpose of trial. The surface is then rolled with a steam roller weighing 300 lbs. per inch run of large disk. No difference is observable between rolling with cold or heated roller. The disks of the roller are kept moistened with crude petroleum, which prevents any tendency to pick up the top coat, and when the proper proportions are observed no trouble is experienced from the machine shoving the material ahead, this occurring when the mixture is too rich in asphaltic cement. After being compressed the thickness of wearing surface is two inches.

The gutters are painted with asphaltic cement ironed in, the object being to prevent the degradation that occurs at this portion of the carriageway, caused mainly by the fact that this portion of the carriageway does not share with the traffic compression produced at the other parts of the roadway.

Trouble has been experienced on pavements alongside of street railroad tracks, the cross ties of which, if not well ballasted, move up and down sufficiently to break the pavement over them and leave ugly ridges. The tendency to cut into ruts alongside of the rail is counteracted by laying granite blocks eight inches by four inches by six inches alternately as header and stretcher bedded in mastic, the toothing thus formed obviating this tendency to rut.

The above described pavement, when honestly proportioned and laid, possesses all the elements which go towards making a good pavement, and it is not expensive, costing at the present time about $1.75 per square yard.

I agree with Mr. North that a bond for maintenance for a term of years should be required from the contractor for this class of work, there being so much of honesty and skill required in refining and manipulating the materials composing it.

E. P. North—I would like to ask Mr. McComb how much clay is left in Trinidad bitumen and how it is refined.

D. E. McComb—There is supposed to be left in the refined bitumen twelve per cent. of impurities, it being practically impossible to refine it so that it will have a smaller percentage of impurities than that.

Note on the Nomenclature of Bitumens.

BY EDWARD P. NORTH.

While such strenuous efforts are being made for uniformity in the matter of measures, the nomenclature of bitumens should secure attention.

In Paris, and in France generally, the nomenclature of M. Malo and others as given in Transactions, Vol. VIII, page 121 (May. 1879), is used. Colonel Haywood also employs it in the specifications and reports of the City of London, and it is believed that all dealers and manufacturers of asphaltes use the same nomenclature.

On the other hand, in this country dealers in Trinidad bitumen and its mixture, almost invariably call their compounds asphalt or asphaltum. Tar Pavers and roofers also apply the same names to their products, both calling such asphaltes as are capable of compression Neuchatel, apparently because the Val de Travers asphalte happened to have been imported into this country by a branch of the "Neuchatel Asphalte Company, Limited," of London, which bought out "La Societe Generale de Asphaltes de Suisse," but could not take the name Val de Travers as there was at that time an organized company in London bearing that name. Val de Travers asphalte is not called Neuchatel in any part of Europe, besides which there are at least three other asphaltes that can be compressed, besides many others that are used for mastics.

As the distinction between asphalt or asphaltum on the one hand, and asphalte on the other is too slight to attract the attention of any but

a critical reader, the advisability of following Malo's nomenclature is submitted to the Society as the most logical and convenient.

F. Rinecker, of Wurzburg, Germany (through the Secretary).—Besides the methods of paving described in the paper of Mr. North the following may be worthy of a short mention :

Brick pavement, especially in Holland, where very hard brick, *Klinker*, is used for this purpose.

Flag pavement, in many Italian towns, consisting of large slabs, laid in rows for the wheels to run over, the balance of the street being common pavement.

Concrete pavement, which (if I am correct) was tried in Paris and New York. I am ignorant of the results, however. I have seen some sidewalks and depot platforms in Germany, which wear well. For traffic it will be worthy of consideration, whether the broken stone or gravel used in the concrete should not be of the same hardness as the cement to insure equal wear. In using harder stone the unequal wear might be a cause of failure.

In selecting any system for covering roads and streets uniformity is necessary throughout a whole city, at least in its main thoroughfares. The safety of horses greatly depends on their shoes, but the patterns of the shoes differ with the roads on which they are to be used. The connection between shoes and roads needs no comment, and in my opinion it is a grave mistake to use stone in one street and wood in another, when the same traffic has to run over them both.

I attach some notes taken from German and French periodicals, the figures of which I have reduced to United States standards.

As to the cost of some pavements to the square yard, the "*Deutsche Bauzeitung*," 1877, has the following :

	Vienna.	London.		
	Granite.	Granite.	Asphalte.	Wood.
Durability, years,	35	15.6	17	11.34
Cost of construction, $	3.07 to 3.37	3.77	3.80	3.20
Total cost of maintenance, $	1.74	1.40	3.27	3.37
Aggregate cost averaging to one year, cents,	13	37	34	62

From experience at Buda-Pesth the following data for 15 years are furnished :

	Granite on				
	Broken Stone.	Concrete.	Trachyte, on Broken Stone.	Wood.	Asphalte, Comprimé* on Concrete.
Thickness of pavement, inches,	7.1	7.1	7.1	?	2.36 to 2.76
" " foundation, "	6.3	6.3	6.3	?	9.7
Cost of construction, $	4.50	5.05	5.50	3.00	4.35
Total cost of maintenance, $	2.40	1.80	3.00	6.00	3.00
Aggregate cost of 15 years, averaging to one year, cents,	46	45	57	60	49

The paving stones of Paris are described in "Romberg's Zeitschrift f. pract. Baukunst," 1878, as follows :

According to the specifications a distinction is made between large and small blocks.

Large blocks to be 7.9 to 9.2 inches long, 6.3 to 9.2 inches wide, and 7.9 to 9.2 inches high.

Small blocks to be 6.3 inches long, 3.9 inches wide, and 6.3 inches high. The latter, "*paves de petit echantillon*," are preferred of late. Differences in size to 0.4 inch are admitted.

On account of the bond a certain percentage to be blocks one and one-half times as long as specified above, "*boutisses*."

According to the dressing two qualities are distinguished : smooth and rectangular blocks for joints of only 0.2 inch, and rough ones for joints up to 0.6 inch.

The material is sandstone "*gres d'yvette des Vosges*," or "*de l'Ourthe*," and porphyry from Belgium and Bavaria. This porphyry, however, has not given satisfaction, wearing too smoothly.

The price is $44 to $125 the thousand, and $8 to $13 additional for dressing.

The Macadam is being replaced where annual repairs exceed 50 cents the square yard.

As to the cost of the Paris pavements the following notes are from "Annales des ponts et chaussées," 1877 and 1878 :

	Pavement.	Macadam.	Asphalte.
Cost of construction.....	$2.55 to $3.45	?	$1.93 to $2.42
Annual cost of maintenance, cents	9.6	29.0	17.7

* Asphalte comprimé is the French term for the compressed powder.

The wear of Macadam amounting to 23.37 cubic yards to the mile and 100 horses.

Annual cost of maintenance to the square yard :

	1872-75.	1876.	1878.
Pavements, cents	7.7	8.2	8.5
Asphalte, "	19.3	20.9	20.4
Macadam, "	29.0	34.0	32.2

The watering with carts costs—

On Macadam, 19.3 cents to 1 000 square yards.

On pavements, 9.6 " " "

J. B. Dumas, Assistant Engineer of the City of Paris, published comparative estimates in "Nouv, Ann. de la Constr," 1878–79, from which the following data are compiled :

Cost of construction.	Price to the yard.
Pavement of rectangular blocks, "*gres*," 3.9 by 6.3 by 6.3 inches..	$3 22
Macadam of silex	1 61
" " meuliere	1 84
" " porphyre	1 98
Asphalte comprimé, 2 inches thick on 3.9 inches of concrete.	
Using for the latter hydraulic lime	2 93
" " Roman cement	3 08
" " Portland	3 15
Each inch of asphalte above 2 inches additional	1 05
Wood pavement, Trenaunay	2 76
" " Norris	4 31

Annual cost of maintenance and repairs :

Repaving	24 to 64 cents.
Asphalte, roadway	21 "
" crossings	32 "
" sidewalk	4.8 "
Macadam, silex	47 "
" meuliere	55 "
" porphyre	129 "
Wood pavement	56 "

Both systems of wood pavements f.iled in streets with high traffic.

Experiments with asphalte coulé* have shown its unfitness for wagon traffic.

* Asphalte coulé (poured) is the French term for Mastic.

THE ENGINEER, 1878, Vol. XLVI., p. 358, ascribes the invention of the Macadam to John Lochhead in 1794.

J. J. R. CROES.—Referring to the amount of water used for keeping down the dust on Macadamized roads (p. 113), the following may be of interest :

In the year 1872 an account was kept of the water used on the drives in the Central Park in New York city.

The length of carriage ways is 9.435 miles, of widths from 30 to 60 feet, averaging 54 feet. The area occupied, including spaces for carriages in waiting, is very nearly 250 000 square yards. The carts used for watering are in the form of a segment of a cylinder of 35 inches diameter, the height being 26½ inches and the chord 20 inches. The barrel is 90½ inches long, and contains 40.7 cubic feet of water.

During the season of 1872, from April 1st to Oct. 31st, the roads were sprinkled on 136 days, using 81 305 barrels of water, or 3 309 114 cubic feet, an average of 24 332 cubic feet per day, or 97⅓ cubic feet per day for each 1 000 square yards. The greatest amount used in any one day was on July 1st, when the temperature ranged from 77° to 93° F. and 929 barrels or 37 810 cubic feet of water were used ; an average of 151¼ cubic feet per 1 000 square yards.

The next greatest amount used was on June 22d, when the temperature ranged from 70° to 86° F., and 890 barrels or 36 223 cubic feet of water were distributed ; an average of about 145 cubic feet per 1 000 square yards.

At least one half of the area watered was sprinkled twice as often as the other half, in consequence of its greater exposure and the greater travel upon it.

I am informed that during the summer of 1879 the carriage way of Fifth avenue from Twenty-third to Thirty-fourth street, 0.55 mile in length and 40 feet wide, embracing 12 907 square yards, was kept watered by six carts holding 70 cubic feet each, and making from 3 to 6 trips per day. This would make the amount of water used from 97.5 to 195 cubic feet per 1 000 square yards. The pavement is of trap blocks.

E. B. VAN WINKLE.—Referring to page 95 of Mr. North's paper : The form of roller proposed for the upper layers of earth roads, namely, large and smaller sized disks placed alternately on the axis of the roller, I have seen used with excellent effect on an embankment, and it could

doubtless be so used for the foundation of earth roads, but is unsuitable for surfacing and road maintenance. The ridges left by the use of this form of roller would tend to carry surface water longitudinally instead of the shortest distance transversely to the gutters.

I believe it would be found very efficacious and economical in the maintenance of earth roads to have the regular passage over them—one or more times, according to their importance—of a moderately heavy two-horse roller a few hours after the cessation of rains. About one roller to every twenty miles of ordinary road should be kept provided.

Referring to page 96 : I should think it questionable whether the addition of hard pan to a clay road would be of use.

Referring to pages 99 and 100 : It would be interesting to know the results of a combination of the first and last of the systems of rolling Macadam roads enumerated by Mr. North, that is, steam rolled and traffic made. I would suggest that the steam roller be first used without binding material, or with very little, to bring the road metal to a passable surface, and then open the road to traffic.

My experience coincides with that of Mr. North—that the hardest kind of stone, if of the proper size, will produce a firmer roadbed when traffic made, without softer binding material.

Referring to page 102: The reason why the Macadam in Basnat street, Liverpool, does not show the wearing qualities of a well puddled trap road I conceive to be not on account of the binding material—coal tar, pitch, &c.—but owing to imperfect consolidation due to hand rolling. I have no doubt that, the rolling being equal in all cases, a binding material of pitch as described would give better results than where cement, clay, or "hoggin" were used, as less water would reach the foundation, and the pitch would have more elasticity, giving somewhat without breaking or crushing.

Referring to page 103: M. Malo's picturesque description of the Macadamized streets of Paris will apply with equal force to London or New York.

As far as I have any experience, Macadam pavements are a failure for city streets, except in some isolated cases where the traffic is merely nominal, or where all other considerations except pleasure driving are out of the question.

Referring to page 110 : One great reason for the unexpected success of Mott avenue was, in all probability, that the heavy rolling over the saturated fresh filling of earth of the road (some four or five feet in

depth) most thoroughly compacted it, hence, giving subsequently a very solid foundation for the Macadam.

Referring to pages 112 and 113: The transverse section of a pavement is most important. The general tendency is to give too much crown to the pavement. In streets where there are horse railroads this crowning has generally become excessive, the trackmen tending always to raise the track regardless of any established street grade, while the city employés who repair the pavements meekly assume that the track is at grade and pave flush with it, while at the same time the curb is maintained at grade or settles below it. It would seem proper that the authorities in charge of street roadways should, at the time a railroad is being built, determine a proper profile for it. This profile should be filed, and the railroad forced to conform to it.

Another fallacy is, that an excessive amount of crowning adds to the strength of the pavement on the principle of an arch, the paving blocks being the voussoirs and the curbstones the skewbacks. The absurdity of this illusion is readily apparent if we conceive of an arch of 30 to 60 feet span with a versed sine of one foot or less, skewbacks half a foot thick resting on compressible earth, and, more wonderful still, the voussoirs in contact only at the extrados. The greater the crown given to a pavement the less will the depressions resulting from poor paving be noticeable on account of holding water.

In an earth road the transverse slope should never be less than the longitudinal slope. This restriction I consider unimportant in a stone block pavement, as with this class of pavements there is no danger of ruts being formed by running water, while it is quite desirable to have the rainfall scour quite an extent of the pavement surface before reaching the gutters.

Gillespie says that the proper section of roadway surface should be formed by two planes inclined from the gutters upward towards the centre of the roadway, with their intersection rounded by a slight curve.

That this is correct I have tried to believe for a long time, but observation convinces me that it is not the best form. The arc of a circle is practically the best cross section for street pavements. If not from choice, at least from necessity, the bulk of travel is along the centre of the street, the portions on each side next the curb being occupied by vehicles standing. With a section of the arc of a circle the centre of the roadway is almost level. Another advantage is, that while the gutters are running full, the width of deep water is narrower than when the surface is an inclined plane.

Referring to page 114 : I fully agree with Mr. North as to the excellence of granite pavements in England. London, particularly, excels in the quality of its stone block pavements. I have seen nothing elsewhere equal to them for streets of heavy traffic. Their great superiority arises principally from their concrete foundations. It is surprising that similar foundations are not always used when the streets in the business portion of the city are relaid with stone blocks. The filling of the joints between the blocks with pitch I think would be a decided improvement upon the London plan of grouting.

Referring to page 115 : Wood pavements, as far I have any experience have been without exception, a failure. I can conceive that creosoting the blocks and filling the joints with bitumen would prevent decay, and thereby materially lengthen the life of this class of pavements, but, so far, nothing has been—and in all probability never will be—invented that will prevent wood, when subjected to an incessant impact and attrition of iron horseshoes and heavily loaded steel tires from acting as wood—that is quickly wearing down. The pits in the surface of wooden pavements have been proved by borings to be due much more to the actual wearing off of the wood than to settlement.

Referring to page 130 : My recollection of those sidewalks in Paris covered with asphaltic mastic ("bitumen" so called) is, that they are not very satisfactory. During July and August almost every footstep left an impression in the mastic, and in winter they were excessively muddy, and had generally sunk out of plane.

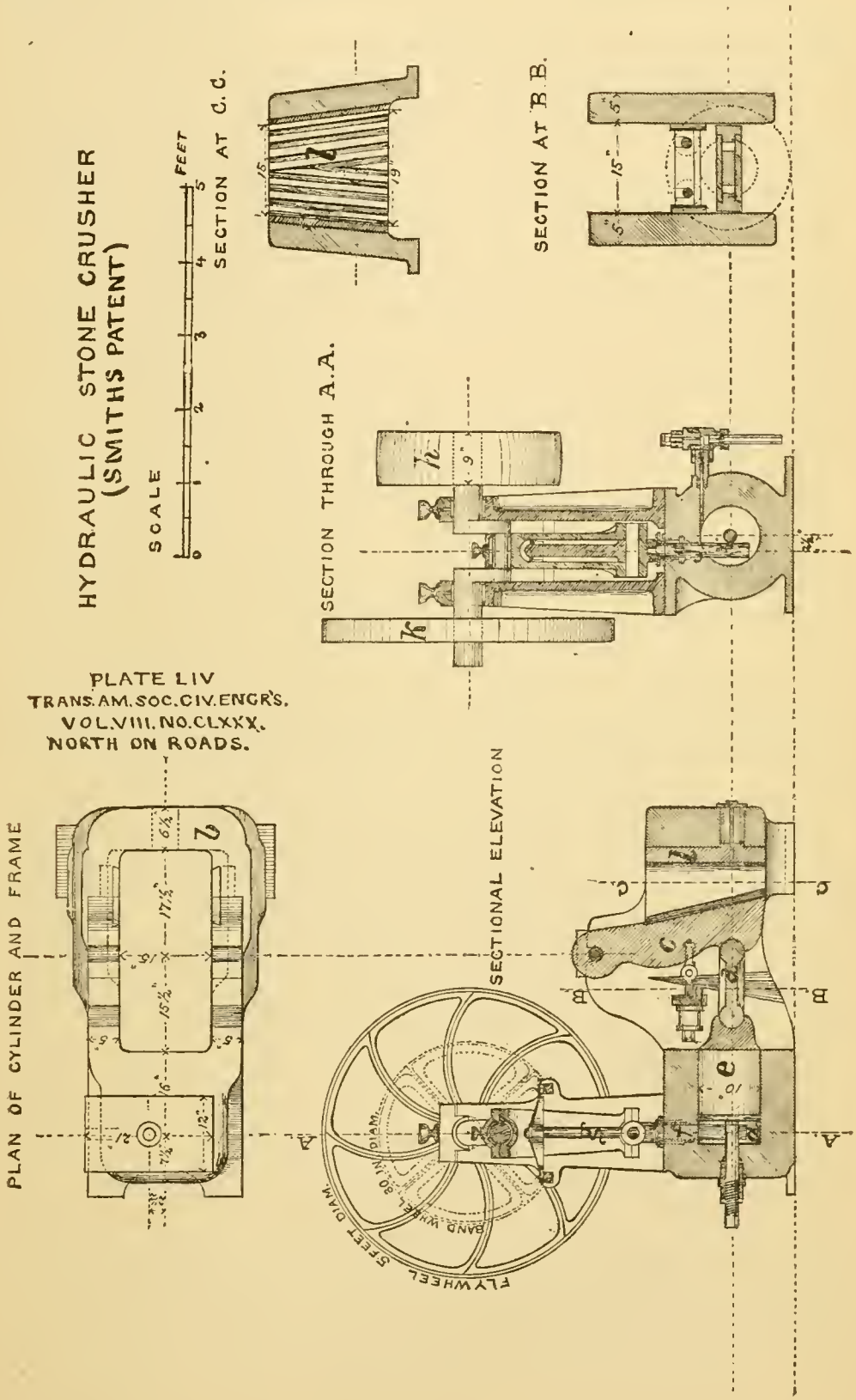
Have any experiments ever been made with the bituminous limestones found in this country to use them as paving material in the same manner as the regular asphalte ?

John Bogart.—Experiments were made some years ago in Chicago with a peculiar limestone, which it was thought might be utilized in a manner similar to the imported asphalte. The result was a good Macadam pavement, but apparently the impregnating matter had no advantageous effect—my recollection is that it was petroleum rather than bitumen, and that it did not exert any cohesive force.

C. C. Martin.—The Smith Hydraulic Stone Crusher as now manufactured possesses *two* peculiarities which render it superior in certain respects to former patents:

First.—The power is applied through an hydraulic cylinder, which has connected with it a safety-valve.

Second.—The opening through which the stones pass after being crushed is wider at the bottom than at the top, as shown by the cross-section at *c c*. Plate LIV.



These are the two essentially novel and good features of the machine; all of the rest are simply mechanical arrangements for transmitting the power from the engine to the machine, and may be arranged as here shown, or in any other way. In this machine *a* is the hydraulic cylinder, *b* is the frame, *c* is the movable jaw, *d* the toggle, *e* the hydraulic ram, *f* the plunger, *g* the connecting rod, *h* the band-wheel, *k* the fly-wheel, *l* the stationary jaw; the section *c c* is a front elevation of the stationary jaw. When the machine is to be made ready for use the ram, *e*, is drawn back so as to place the movable jaw, *c*, far enough from the fixed jaw, *l*, to permit stones of the largest required size to pass through between them; the plunger, *f*, is drawn up out of the hydraulic cylinder, *a*, and the cylinder is then filled with water or other liquid, and the safety-valve is weighted. The operation of the machine is as follows: Stones are thrown between the jaws and the engine started; as the crank-shaft revolves the plunger, *f*, is forced down into the liquid, and displacing a portion of it forces the ram forward, which, through the toggle, *d*, presses the movable jaw against the stone, which is crushed. The upward movement of the crank withdraws the plunger, and the ram is drawn back to its original position, and the jaw is again opened; thus, every revolution of the crank shaft produces one stroke of the jaw. The machine works well, running at two hundred to two hundred and fifty revolutions per minute, and will readily and regularly break seventy-five cubic yards of limestone in ten hours, to sizes varying from 1½ to 2½ inches largest dimensions

The advantage of the safety-valve is, that in case any stone which cannot be broken, a sledge hammer dropped from the hands of a careless workman, or any other unyielding body, gets between the jaws, the only effect is to force open the safety-valve and permit the escape of a portion of the liquid from the cylinder, thus stopping the motion of the jaw without stopping or changing the motion of the fly-wheel. The liquid thus discharged is received in a small tank, and the continued motion of the machine pumps it back into the cylinder, and the crushing goes on. If the obstruction still continues, the safety-valve is again opened. The result of this safety attachment is that the machine is never broken.

The advantages of widening the jaw at the bottom are two-fold, as will appear from a consideration of the operation of the stone in the crusher. The broken stones occupy more space than the unbroken, and the smaller the pieces the more space do they occupy. The stone entering at the top of the jaw is broken, and each successive stroke crushes it

more, and in the old style of jaw the stone became clogged and many pieces were ground to powder before they could escape, thus wearing out the jaws and cheek pieces, and consuming unnecessarily a large amount of power. The widened jaws permit the stones to escape as soon as they are broken, thus leaving them of more uniform size, making less dust, and breaking them with the least possible expenditure of power.

Edward P. North.—Regarding objections made to certain clauses in the paper under discussion, it may be said that the roller with unequal sized disks was not advised for maintenance, but unless it was so guided that the larger disks always followed the same tracks its use would cause less tendency to longitudinal ruts in the road than the ordinary traffic.

The advisability of surfacing a clay road with hard pan must depend greatly on the character of the hard pan—a clay hard pan might be objectionable.

Messrs. Spielman & Brush's practice, as detailed on p. 333, is undoubtedly sound under the circumstances, viz.: an absence of water for compacting and puddling, but a better road, with less tendency to internal wear, would have been formed by a steam roller, if sufficient water could have been procured.

Lavoinne seems to have misunderstood the effect of the screenings, *i. e.*, small fragments of stone from the breakers. The coarser of these are applied only when compacting has proceeded so far that the stones have a tendency to roll over one another and round their angles; these screenings bind the stone and prevent to a great extent further wear. About 33 per cent. of screenings are worked into the metal and are used in puddling. Probably about 25 per cent. of this is coarse screenings in the interstices between the stones, the rest being fine screenings and that used in puddling.

Law & Clarke, p. 145, give 10 or 11 cubic feet interspace per yard—40 per cent in compacted stone. In Paris, about 24 per cent of sand is used in binding, and, as above stated, 33 per cent. of screenings are used here.

It was not the intention to argue for poorly constructed wooden pavements, but rather to show the practice where wood pavements are successful, with the hope that it might be followed in this country. The fact that wood pavements as usually constructed here and never repaired have proved failures, cannot be denied, but that a well made and intelligently maintained wood pavement would be a failure is doubted.

The following memorandum from Cleveland confirms this view: "In the year 1873, 5 070 square yards of creosoted wooden pavement were laid in Franklin street, Cleveland. The pine blocks were creosoted with about 4 lbs. of oil per cubic foot. Since that time no money has been expended in maintenance, and the pavement is in excellent order.

At the same time, and in the same street, an equal area was laid with blocks prepared by the "Thilmany" process; of this, 1 400 square yards have been relaid by the city."

It is unfortunate that the asphalte pavements in Washington were so poorly laid.

I street has such an excessive crown, that it is only in the center of the wheelway that the street is sufficiently flat for ease or comfort in driving.

On Pennsylvania avenue the transverse profile is good, but the heated powder was apparently laid on damp concrete, and the surface is badly cracked in consequence, and has been extensively repaired, though it was laid in the fall of 1877, and it is doubtful if it wears more than five years in all.

In Paris, with a much heavier traffic, asphalte lasts 15 years.

The bituminous mastic pavements described by Mr. McComb present very fine surfaces, and, if they wear as well as now hoped, will have all the advantages of compressed asphalte, except durability, at reduced cost, and their use may be advisable in streets of light traffic.

The present practice is to make the wearing surfaces harder than has been usual, it having been held that *all* mastic pavements, subjected to street traffic, should be made so soft as to dent in summer, to prevent their breaking up in winter.

The weak point of bituminous mastics seems to lie in the expense necessary to free the Trinidad bitumen from clay, and the difficulty of getting sand that is free from clay, and fine enough to absorb sufficient bitumen for cohesion in cold weather, without an excess in hot weather. Loam or loamy sand was used at first to enable the mixture to carry sufficient bitumen for wear, but the rapid rotting in the gutters, and at other points where water lies, has led to the use of 15 to 16 per cent. of limestone, ground to pass through a sieve with 26 meshes to the inch, which probably will not be so detrimental to the mastic as clay.

In reply to a question as to the amount of clay allowed in mastic work in Europe, M. Leon Malo writes: "In principle, no clay at all

ought to be in mastic; the asphalte rock, being quite pure limestone, is desired to be mixed with quite pure bitumen. But, in reality, the bitumen of Trinidad having been generally adopted in works by want of pure mineral bitumen, and as it is impossible to quite deprive that bitumen of its clay, it is admitted that the clay brought into the asphalte works by the Trinidad bitumen can be accepted; that is to say, from 2 to 3 per cent. of clay in the mastic. For the compressed asphalte, to which no bitumen is added, not one quantity of clay is allowed."

Regarding the asphaltic mastic sidewalks of Paris, it should be noted that there is always a temptation on the part of the mastic workers to use too much bitumen, as the larger the percentage the more easily the mastic is worked; and, unless it is kept very low, the pavement will dent in hot weather. The mud must have been brought on from the wheelways, as, according to Chabrier, the mastic sidewalks under the arcades of the Rue de Rivoli, Paris, wore about half an inch in 13 years—too small a wear to produce much mud.

The necessity for better pavements than those offered by the prevalent granite blocks, will justify the insertion of a translation from M. Leon Malo's "*Note sur L'Etat Actuel de L'Industrie de L'Asphalte, Paris*, 1879."

The experiment of compressed asphalte for carriageways has now been made. It has shown its defects and its advantages; we do not hesitate to say that its advantages far exceed its defects.

We do not now speak of its noiselessness nor of its precious property of creating neither dust nor mud; of its agreeable aspect to the eye, which is a quality not to be neglected in the *ensemble* of the embellishment of a city; we have shown the importance of these in our first work. We insist only on its action upon the public health; a point which we did not sufficiently emphasize.

The asphalte, placed over the soil, like a layer of caoutchouc, absolutely intercepts any communication between the soil and the atmosphere; it does not allow rain water, which runs rapidly into the sewers, to penetrate; and thanks to its water-repelling ("*hydrofuge*") character, the carriageways dry as soon as the rain has ceased.

A stone pavement, on the contrary, permits a constant communication between the soil and air through its joints. All the impurities of the surface, dissolved by the surface waters, are by them carried into the earth; then, when the sun strikes it, these impure waters are evaporated,

returning miasma, bred below the pavement, into the air; it is an evil which has been long recognized and uncontested, but against which no remedy is known.

The system of joining pavements with asphaltic mastic might, perhaps, obviate it, but it is very costly, and renders the carriageway extremely hard for vehicles. Compressed asphalte seems to have solved the problem; and we are compelled to think that of all the services which it can render, this is the most efficacious and the most precious. To be sure, the influence of deleterious miasmas radiated from the different systems of pavements with open joints, cannot be analysed in a precise manner; it is judged rather by induction than by a direct observation which can be put in figures; but it is not the less evident and not the less to be dreaded.

M. Malo also gives the following tabulated results of analysis made in the laboratory de L'Ecole des Pouts et Chaussées on different asphaltes:

	Val de Travers.	Seyssel.	Lobsan.	Sicilian.	Maestu.	Forens.
Water and matter volatile at 212° F[1]	0.50	1.90	3.40	0.80	0.40	0.25
Bitumen	10.10	8.00	11.90[2]	8.85	8.80	2.25
Carbonate of lime	87.95	89.55	69.00	87.50	9.15	97.00
Silicious sand	"	"	3.05	0.60	57.40	"
Aluminum and peroxide of iron	0.25	0.15	5.70[3]	0.90	4.35	0.15
Sulphur	"	"	5.00	"	"	"
Carbonate of magnesia	0.30	0.10	0.30	0.95	8.10	0.20
Different minerals insoluble in acids	0.45	0.10	"	"	11.35	0.05
Loss	0.45	0.20	1.65	0.40	0.45	0.10
	100.00	100.00	100.00	100.00	100.00	100.00

NOTES: 1. The water given above depends on the dryness of the sample at the time of analysis; the figures not being of importance in the results.

2. This quantity appeared to contain a certain proportion of oil, which was mixed with the bitumen and was not exactly determined.

3. This comprises 4.45 of iron, combined with sulphur.

M. Durand-Claye, Director of the laboratory, speaking of the Lobsan, says: "It contains about 9½ per cent. of pyrites, which may become the cause of failure in employing this material. The heat to which it is submitted may cause it to lose half of its sulphur, and be transformed into protosulphate of iron, an oxydizable material, which by exposure to the air is transformed into a soluble sulphate of iron; disintegration might result from this a short time after putting it in place."

Mr. H. F. Starr, of the Columbia College School of Mines, kindly made an analysis of some Limmer asphalte, which gave the following result:

Bitumen	8.26
Clay	4.98
Carbonate of lime	56.54
Carbonate of magnesia	27.01
Sesqui oxide of iron	3.21
	100.00

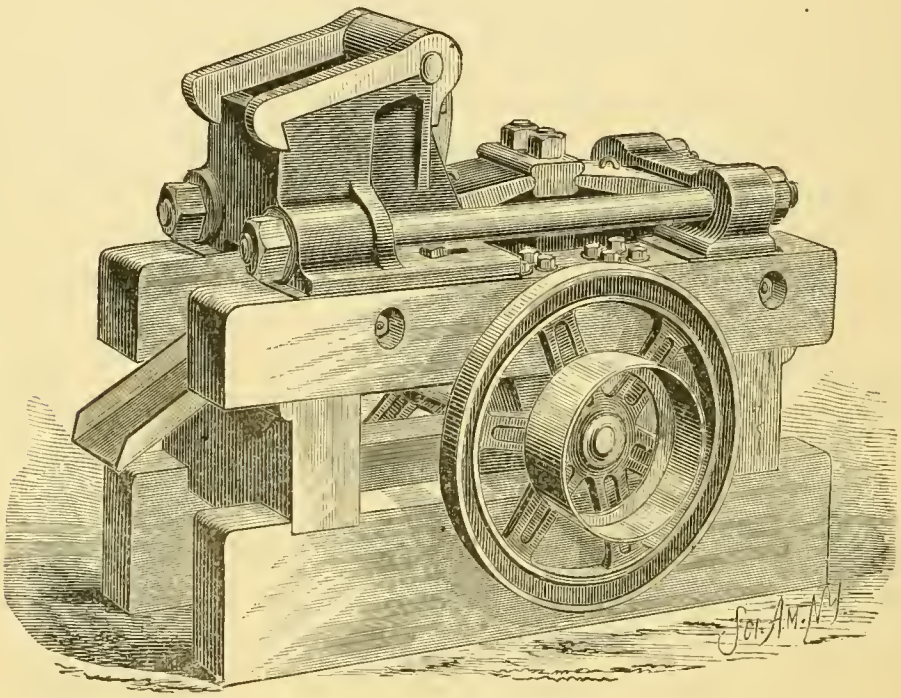
This is the only analysis I have seen of an asphalte that will not compress, and the only one, excepting the Maestu, in which there is over 1 per cent. of carbonate of magnesia.

M. Malo gives analyses of seven different cargoes of crude Trinidad bitumen. In each case the samples were thoroughly dried, losing from 32 to 38 per cent., after which the average of the analysis was bitumen 51½, and clay 48½ per cent. The greatest percentage of bitumen in any sample was 57.55, and the least 45.

In addition to the description of the hydraulic crusher furnished by Mr. Martin, a mention of the new Blake crusher may be of interest. See figure.

In it the old cast-iron frame is replaced by steel rods and a wooden frame, so cushioned that the fly-wheel, in case of abnormal resistance, can make a part of a revolution. The pitman, which is above the driving-axle, can be lengthened or shortened, so as to increase or diminish

the stroke of the jaws, and the length of the toggles has been increased. It is probable that these changes will reduce the expense of stone-breaking by diminishing the breakage account, which, particularly with trap rock, is a serious item.



Mr. J. L. Gillespie, C.E., gives me the following as the cost of breaking 15 150 c. yards of limestone during 1874–5–6–7, for the concrete used in the preservation of the Falls of St. Anthony. The machine, an 8″×16″, old pattern Blake, was run by water power, for which there was no charge.

The cost and quantities were as follows, the stone being delivered at the breaker :

1874–5	3 452 c. yds.	at	41.	cents.
1875–6	8 284	"	31.8	"
1876–7	3 414	"	18.	"

1 c. yd. of stone produced about 2 c. yds. of broken stone, the void spaces in which amounted to $50\frac{8}{10}$ per cent. The breakages were confined to some rubber springs, 1 back block, and 2 sets of jaws and cheeks.

The cost of breaking trap on the Palisades is given as follows, the stone being sledged, to go into the jaws readily.

Two crushers deliver 35 c. yds, of 2″ stone per day, when working well; 15 per cent. of the time is lost by breakdowns.

COST.

1 Engineman and fireman, at $2 50	..	$2 50	
2 Laborers, feeding..... 1 25	..	2 50	
2 " screening..... 1 25	..	2 50	
		——	$7 50
Coal, 1 ton.....			3 50
Oil and waste.....			1 00
Breakages			5 00
			$17 00

or, say 57 cents per c. yd.

On Snake Island three crushers were arranged in a row, and the broken stone was carried by an endless belt to the revolving screen, whence it fell into the bins, so that no screeners were employed. The engine had one cylinder, 8″×24″, and was running with 80 pounds of steam. The product was said to be 180 c. yds. per day when there was no breakdown.

COST.

1 Engineman and fireman, at $2 50	..	$2 50	
3 Laborers, feeding..... 1 25	..	3 75	
		——	$6 25
2½ tons of coal, at $3 50.....			8 75
Oil, &c.			2 00
Breakages			15 00
			$32 00

Allowing for the 15 per cent. lost by breakdowns, the cost would be about 21 cents per c. yd.

At another place on the Hudson, 2 crushers, set face to face, 9″×15″ jaws, could deliver at the rate of 120 c. yds. per day, when no trouble occurred, but 100 c. yds. was a fair average.

COST.

Engineman and fireman	$2 50	
3 Feeders	3 75	
2 Screeners	2 50	
		$8 75
1½ tons coal, at $4		6 00
Oil, &c		2 25
Repairs		10 00
		$27 00

or 27 cents per c. yd.

NOTE.—A detailed statement of the cost, in time, of breaking stone is given in the Memoir on the Construction of a Masonry Dam, by J. J. R. Croes. Transactions of this Society, No. CIII., Vol. VIII., page 356 (February, 1875).—[EDITOR.]

APPENDIX NO. 6.

SPECIFICATIONS FOR THILMANISING LUMBER FOR MINNEHAHA BRIDGE.

C. Shaler Smith, Consulting Engineer.

Steaming.

After being placed in the cylinder, the lumber shall be exposed to a steam bath which shall be continued for 90 minutes, for sticks under 10 feet in length, and nine minutes additional for each additional foot of length of the sticks treated, or until an analysis shows that the albumen of the sap has been completely coagulated, and the watery part thoroughly diluted or vaporized so as to flow freely.

During this process, the steam must not at any time exceed 240° F. in temperature, or 5 pounds in pressure per square inch in the receiving cylinder.

Vacuum.

On the completion of the steaming,—the steam shall be shut off, and a vacuum of not less than eleven pounds, produced in the receiving cylinder by the use of a vacuum pump,—which vacuum shall be maintained for 40 minutes, for sticks less than ten feet in length, and six minutes additional for each additional foot, or until moisture has ceased to flow from the wood.

First Injection.

A solution of sulphate of zinc, made by dissolving one pound of salt in fifty pounds of water, and having a specific gravity of 1.012, shall then be let into the cylinder from its lowest point, while the vacuum is still being maintained by the vacuum pump,—the supply pipe of which shall issue from the highest point of the cylinder. When the cylinder is filled with the solution, an injection pump shall be used to attain a pressure of 100 pounds per square inch, which pressure shall be maintained until the solution has penetrated every part of the wood under treatment. The time requisite for this shall be fixed by the Inspector after an experimental test or tests to determine it.

Second Injection.

After the zinc solution has been drawn off from the cylinder, a light vacuum of four pounds shall be produced by use of the vacuum pump, and a solution of chloride of barium, made by dissolving one pound of the salt in forty-five pounds of water, and having a specific gravity of 1.021, shall be let in as prescribed in the case of the first injection, during the maintainance of the vacuum, and then a subsequent pressure of 100 pounds per square inch shall be produced, and continued until the penetration of the wood by the barium

solution is complete, and all the pores of the wood are fully charged with the resultant salts of chloride of zinc and sulphate of barium. No uncombined zinc or free sulphuric or muriatic acids, shall be left in the wood after this last process, and the time required to effect these results shall be fixed by the Inspector after experimental tests covering all the varieties of lumber and length of sticks included in the contract, to which these specifications shall be attached.

General Specifications.

Where sticks of various lengths are contained in the same charge, the length of the longest stick shall fix the time required for the several processes.

Where different varieties of wood are included in the same charge, the time for each process shall be based upon that wood which requires the longest time in treatment.

Where wood is burnt by long continued steaming, or by superheated steam, it shall be rejected entirely, and shall be replaced by the Wood Preserving Company, at its own expense, if the deterioration is due to a violation of these specifications. Where sticks are found to be imperfectly de-albumenized, or insufficiently injected, they shall be treated a second time, or until they are completely charged as above specified.

After each solution is drawn off into its tank it shall be tested, and its percentage of the salt brought up to the standard herein specified before it is used again.

Should either solution become objectionably impure from frequent use, it shall be run out of the tank and a fresh solution shall be made.

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— February 5th, 1879, Result of ballot to determine place of Eleventh Annual Convention; Cleveland to be the place; ballots for membership canvassed; "Engineering Questions Involved in the Development of Electric Lighting," by Stephen Chester, read and discussed, 3.

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American Society of Civil Engineers.

PROCEEDINGS.

Vol. V.—January, 1879.

[Up to April 2d, 1879.]

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

January 3d, 1879.—The Society met at 8 p. m., the President, W. Milnor Roberts, in the chair.

The death of Samuel J. Reeves, Member A. S. C. E., was announced, and the President was authorized to appoint a committee to prepare a memoir.

The result of the canvass of the ballots for proposed Amendments to the Constitution and By-Laws, was as follows:

Upon the Codification of the Constitution and By-Laws, as printed in Proceedings, Vol. IV., page 95 (July, 1878), there were 74 Ayes and 9 Nays. This codification was thereupon declared adopted.

Upon the Amendment (marked K) to Article XVIII. of the Constitution, as printed in Proceedings, Vol. IV., page 106, there were 81 Ayes and 5 Nays. This amendment was thereupon declared adopted.

Upon the Amendment (marked L) to Article XVII. of the Constitution, as printed in Proceedings, Vol. IV., page 107, there were 78 Ayes and 7 Nays. This amendment was thereupon declared adopted.

Upon the Amendment (marked N) to Article XXIII. of the Constitution, as printed in Proceedings, Vol. IV., page 108, there were 64 Ayes and 21 Nays. This amendment was thereupon declared adopted.

Upon the Amendment (marked O) to article XXXII. of the Constitution, as printed in Proceedings, Vol. IV., page 108, there were 79 Ayes and 7 Nays. This amendment was thereupon declared adopted.

Upon the Amendment (marked P), a new Article of the Constitution, as printed in Proceedings, Vol. IV., page 108, there were 71 Ayes and 15 Nays. This amendment was thereupon declared adopted.

Upon the Amendment (marked R) to Section 1 of the By-Laws, as printed in Proceedings, Vol. IV., page 108, there were 80 Ayes and 5 Nays. This amendment was thereupon declared adopted.

Upon the Amendment (marked S) to Section 23 of the By-Laws, as printed in Proceedings, Vol. IV., page 109, there were 80 Ayes and 6 Nays. This amendment was thereupon declared adopted.

Upon the other proposed Amendments to the Constitution and By-Laws, as printed in Proceedings, Vol. IV., pages 105, 106, 107 and 109, the vote was as follows:

Upon proposed Amendment to Article V. of the Constitution (marked B.) 5 Ayes, 81 Nays.

Upon proposed Amendment to Article V. of Constitutien (marked C.), 0 Ayes, 85 Nays.

Upon proposed Amendment to Article V. of Constitution (marked D.), 4 Ayes, 82 Nays.

Upon proposed Amendment to Article VI. of Constitution (marked E.), 5 Ayes, 81 Nays.

Upon proposed Amendment to Article VI. of Constitution (marked F.), 4 Ayes, 82 Nays.

Upon proposed Amendment to Article VI. of Constitution (marked G.), 1 Aye, 84 Nays.

Upon proposed Amendment to Article VII. of Constitution (marked H.), 3 Ayes, 82 Nays.

Upon proposed Amendment to Article IX. of Constitution (marked I.), 9 Ayes, 76 Nays.

Upon proposed Amendment to Article X. of Constitution (marked J.), 12 Ayes, 75 Nays.

Upon proposed Amendment to Article XIX. of Constitution (marked M.), 11 Ayes, 74 Nays.

Upon proposed Amendment to Section 24 of By-Laws (marked T.), 16 Ayes, 69 Nays.

Whereupon these proposed amendments (B, C, D, E, F, G, H, I, J, M, and T), were declared not adopted.

An address was then made by the President, alluding to his approaching visit to Brazil.*

On motion, the chair was taken by Martin Coryell. The following resolution was adopted:

Resolved, That a committee of three be appointed to draw up resolutions in reference to the departure of the President.

Messrs. Charles Macdonald, Mendes Cohen and J. J. R. Croes, were appointed such committee.

The committee presented the following Preamble and Resolution, which were unanimously adopted :

"Whereas, The President of this Society, Col. W. Milnor Roberts, has announced his intention of withdrawing from the active administration of the duties of his position, in consequence of having entered upon a service of great honor and trust under the Government of Brazil, be it,

"Resolved, That we desire to place on record at this time, our sense of Col. Roberts' services to the profession during his long career as an Engineer.

"Beginning at the age of sixteen on the Union Canal of Pennsylvania, he was intimately associated with the development of the most prominent canals of the country.

"He became identified with the railway system at its first inception, and his name has been connected with many of the important railways of the United States ; notably with the Allegheny Portage, the Harrisburgh and Lancaster, now part of the main line of the Pennsylvania Railroad, the Bellefontaine and Indiana, the Iron Mountain of Missouri, several railroads in Iowa, and the great Northern Pacific Railroad, of which he still remains Chief Engineer.

"His abilities as a Hydraulic Engineer have been recognized in his appointment by the Government to the charge of the Ohio River Improvement, and as one of the Commissioners to advise in regard to the regulation of the mouths of the Mississippi River, in the execution of which duty he visited Europe with the Commission, and examined the principal works of river improvement there.

"He has also been engaged as Consulting Engineer upon many important questions pertaining to the water supply of several of our principal cities.

"During his long connection with the direction of the Society, Col. Roberts' active interest in its affairs has been of great advantage, and his wise counsel has materially aided his colleagues in the settlement of many difficult questions, and the furtherance of the objects of the association.

"While his absence will be seriously felt by them, they are reconciled thereto by the conviction that it will inure to the benefit not only of himself and the enlightened government which has employed him, but of the profession of which he is an honored member."

The President resumed the chair. The reading of the paper announced for this evening was postponed until the next meeting.

January 15th, 1879.—The Society met at 8 p. m., Charles Macdonald in the chair.

A paper presented at the Annual Meeting with the report of the Committee on Resistances of Trains, being a report of experiments upon the resistances of rolling stock, made by A. M. Wellington, under the direction of Charles Paine, was read and discussed.

February 5th, 1879.—The Society met at 8 p. m., William H. Paine in the chair.

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* See page 6.

The ballots to determine the place for the Eleventh Annual Convention were canvassed, and the result announced, as follows:

For St. Louis	73 votes
For Cleveland	82 "
For San Francisco	1 "

In accordance with this vote it was determined that the Eleventh Annual Convention should be held at Cleveland.

The ballots for membership were canvassed and the following candidates were declared elected as members: William H. Bradley, of Boston, Mass., and Hamilton Smith, jr., of San Francisco, Cal.

A paper entitled "Engineering Questions Involved in the Development of Electric Lighting," by Stephen Chester, was read by the author, and discussed by Messrs. Chester, Dresser, Haswell, Morison, Searles and Yardley.

February 19th, 1879.—The Society met at 8 p. m., Past-President William J. McAlpine in the chair.

A paper by Julius H. Striedinger, entitled "Notes on Gelatine Dynamite," was read, and discussed by Messrs. Chanute, Cooper, Emery, Geo. S. Greene, jr., Haswell, Wm. J. McAlpine and Yardley.

March 5th, 1879.—The Society met at 8 p. m., Ashbel Welch in the chair.

The death of Robert G. Hatfield, member American Society Civil Engineers, was announced, and William E. Worthen, James O. Morse and John Bogart were appointed a committee to prepare a memoir of Mr. Hatfield.

The appointment of John Griffen and Alfred P. Boller was announced, as a committee to prepare a memoir of the late Samuel J. Reeves.

The ballot for membership was canvassed, and the following candidates declared elected:—As Members: James E. Bell, of Cincinnati, O., Thomas Egleston, of New York, Montgomery Meigs, of Washington, D. C., and Joseph O. Osgood (elected Junior May 3d, 1876), of Cañon City, Col.

As Associate: Alexander Gordon, of Cincinnati, O.

As Junior: James P. Allen, of Charleston, S. C.

A communication from Moncure Robinson, and a report made by him in the year 1829 embracing the original recommendation for the plan of crossing the Allegheny Mountains by inclined planes, were read, and discussed by Messrs. Compton, Emery, Haswell, North, Searles and Welch.

Additional experiments with dynamite were described by Charles H. Haswell, and the subject of high explosives was discussed by Messrs. North and Striedinger.

March 19th, 1879.—The Society met at 8 p. m., Past President George S. Greene in the chair.

A paper by W. A. G. Emonts, entitled "Parabolic Arches for Masonry," was read and discussed.

An informal discussion followed upon the general policy of the Society.

April 2d, 1879.—The Society met at 8 p. m., Past President George S. Greene in the chair.

The death of Alfred W. Craven, Past President American Society of Civil Engineers, was announced, and the following committee was appointed to prepare a memoir of Mr. Craven: George S. Greene, William E. Worthen, Julius W. Adams and Allan Campbell.

Gen. J. G. Barnard, then read a paper on the construction of the Minot's Ledge Light House, including with it a memoir on the subject by the late Gen. B. S. Alexander.

Gen. J. G. Barnard also presented an account of the settlement of Fort Livingston, Fla., and referred to the probable cause of settlement of Pier 2 of South Street Bridge, Philadelphia.

George W. Dresser gave an account of the foundations of a large hospital in New York City.

Francis Collingwood gave an account of the method of providing for special cases in the foundations of the piers of the New York and Brooklyn Bridge.

The following resolution was offered by Theodore Cooper:

Resolved, That an invitation be extended to the editors of Engineering journals to attend our meetings; and that all reasonable facilities be given them to report such abstracts of the papers and discussions as they may desire to publish.

The question was discussed by Messrs. Chanute, Cooper, Croes, Dresser, G. S. Greene, G. S. Greene, Jr., and Macdonald.

The following rule, adopted by the Board of Direction, was read for the information of the Society:

"That business proceedings are not to be reported for the public press. Notices of meetings held, and of the papers read and discussion thereon, may be reported. Abstracts, giving the general tenor of the papers, &c., may be published in advance of the issue of 'Transactions' if approved by the Secretary."

The resolution offered by Mr. Cooper was then withdrawn by him, and on motion of Mr. O. Chanute, it was referred to the Board of Direction.

Mr. Chanute gave notice that at the next meeting of the Society he would offer the following preamble and resolution:

Whereas, Every possible effort should be made to increase the sphere of usefulness of the Society and to enlarge its membership as well as to promote active intercourse between all its members, therefore, be it

Resolved, That the following suggestions and such others as may be submitted, be printed and distributed among the members, with the request that they shall favor the Secretary as soon as possible with their opinions, as well as with such other suggestions as they may wish to offer, so that action upon the same may be taken at the next convention.

Suggestions.

1st. That provision be made for the holding of more than a single convention in each year for professional intercourse.

2d. That papers be annually invited from members upon subjects of general interest, to be specified by the Board of Direction.

3d. That a system be established to award special recognition for the best papers contributed each year.

4th. That present members be encouraged to propose worthy persons for new members, associates and fellows.

5th. That to promote the discussion of papers, advance copies be issued to such members as may be specially qualified to take part in the same.

6th. That members be encouraged to make use of the facilities of the Society in New York, for obtaining professional information.

NOTES AND MEMORANDA.

REPORTS OF MEETINGS.

Address made by President W. Milnor Roberts, at the meeting of the Society, January 3, 1879.*

The members present are already aware that I have accepted a position as engineer in the service of the Brazilian Government; an appointment unsolicited on my part, and made without my knowledge, upon the nomination of our fellow member, Capt. Eads, to whom the Emperor, Dom Pedro the Second, had addressed an autograph letter, requesting him to nominate an experienced engineer to take the direction of the Improvement of the San Francisco River. At the suggestion of Mr. Borges, the Brazilian Minister, the appointment was afterwards made more general, requiring me to act as engineer upon any of the public improvements the Government might desire. The engagement is for three years from the beginning of January of this year, 1879.

But two months have passed since the members of the Society did me the honor to elect me their President for the present year, and it would have been a great gratification to me to have continued to preside in that honorable position during the entire year. Last year our worthy President, E. S. Chesbrough, of Chicago, being prevented by his professional engagements from attendance at the Society's rooms in this city, devolved most of the duties upon myself as Senior Vice-President, during most of the season. Now it falls to my lot, in consequence of my new engagement, to ask the Senior Vice-President to fulfill the duties which properly belong to the President, and, doubtless, he will do them well.

Those who are familiar with the working of the Board of Direction (and Trustees) of the Society are aware that by far the greater part of the labor naturally and necessarily devolves

* See Minutes, p. 3.

upon the Secretary and the Treasurer, under the instructions and supervision, it is true, of the Board of Directon. To the faithful and intelligent action of these officers much of the past success and present prosperity of the Society are due, and I am quite sure that the same solicitude for the best interests of our members, as a body, will be maintained hereafter by those gentlemen.

The field upon which I am about to engage in South America, though upon the same hemisphere, can only be conveniently approached from the United States by water, and over five thousand miles of ocean intervene between New York and Rio Janeiro, the capital city of Brazil, requiring about twenty days' steaming, or twenty-two days, including the usual stops at St. Thomas, Para, Pernambuco and Bahia. Besides this direct monthly steamship communication, there is regular steam communication between the two countries *via* England, France, Germany, etc., while much of the commerce between the United States and Brazil is still carried by sailing vessels.

This is not my first visit to Brazil; I spent seven years in that country—between 1858 and 1865—as senior partner of the company who built the 2d section of the "Dom Pedro Segunda Railway," at the time deemed to be one of the most difficult works ever projected. Greater works have since been constucted in Europe and on the west coast of South America, but the undertaking of the Brazilian railroads, nearly a quarter of a century ago, exhibited great foresight as well as most liberal enterprise on the part of the Government. With an enlightened and energetic Emperor, devoted to the maintenance of an admirable written Constitution, and ably supported by a Parliament and Council composed of educated gentlemen, the future of Brazil should be very great. In 1865, before leaving that country, I had the honor to take part in calling public attention to the importance of a direct steamship line between Brazil and the United States, which was soon after established, sustained in part by subsidies from both governments. After running some years that line was withdrawn. Recently another line has been put on, and it is to be hoped that the Government and people of the United States will encourage more frequent intercourse between the two countries, to their mutual advantage.

Being so far away, I shall miss the professional and social gatherings of our members, and for a time I will have to content myself with the reading of the published Transactions and Proceedings. I trust, however, that they will lose none of their interest in consequence of the distance they must traverse. Though absent in body, I will be present with you in spirit; and, should there be time and opportunity, I may be able to contribute an occasional paper relating to South America, which may have interest for members in North America.

Ours is the "*American*" Society of Civil Engineers. It knows no "North," no "South," save as amicable, continental designations.

I cannot but feel sad at parting for several years with so many associates and personal friends who have been so uniformly kind, but soon this feeling will give place to pleasurable recollections, which I shall carry with me wherever I go.

I bid you one and all an affectionate adieu. May God bless you all.

LIST OF NEW BOOKS ON

ENGINEERING AND TECHNOLOGY.

Architecture. Town and country mansions and suburban houses, with notes on the sanitary and artistic construction of houses. W. Young, New York. Fol. 30 plates. *Spons.* $12.50.

Army Sacrifices; or, Briefs from Official Pigeon-Holes. Sketches based on Official Reports, grouped together for the purpose of illustrating the services and experiences of the Regular Army of the United States on the Indian Frontier. Maj.-Gen. Jas. B. Fry, U. S. A. New York. 16mo. *Van Nostrand.* $1.00.

Canal and Culvert Tables, based on the formula of Kutter, under a modified classification. With explanatory text and examples. Louis D'A. Jackson. London. 8vo. *W. H. Allen.* 28s.

Cast Iron Pipes. Ernest Benedict. New York. 8vo. *Spons.* $0.20.

Catalogue, The American—— of books in print and for sale on July 1, 1876. Vol. 1. Authors and Titles. Parts 1 and 2. A. to Lennox. By F. Leypoldt and L. E. Jones. New York. Quarto. *Leypoldt.* For the two volumes complete, $25.00.

Coal, The History of —— ; lecture at King's College. T. Wiltshire. London and New York. 8vo. *Spons.* $0.40.

Corals and Coral Islands. Maps and illus. James G. Dana. New York. *Dodd, Mead & Co.* $3.50.

Dampness, Traitè complet sur l'humidité qui se fait sentir dans la plupart des habitations. P. Vienot. Paris. 8vo. New York. *Van Nostrand.* $1.00.

Education as a Science. Alexander Bain. London. 8vo. *C. K. Paul & Co.* 5s.

Electric Light. Farmer on the Electric Light; extracts from "The Speaking Telephone, Electric Light, and other recent electrical inventions." G.S. Prescott. Newport, R. I. 8vo. *C. E. Hammett.* $0.15.

Electric lighting. Useful information on practical electric lighting. Killingsworth Hedges. New York. 8vo. *Spons.* $0.40.

Engineers', Architects' and Contractors' Pocket Book for 1879. London. 12mo, bound. *Crosby Lockwood.* 6s.

Fuel: Its Combustion and Economy. Consisting of Abridgements of a Treatise on the Combustion of Coal and the Prevention of Smoke, by C. W. Williams, and the Economy of Fuel, by T. Symes Prideaux. With extensive Additions on Recent Practice in the Combustion and Economy of Fuel, Coal, Coke, Wood, Peat, Petroleum, &c., by the Editor, D. Kinear Clark. (Weale's Series.) London. 12mo. *Crosby Lockwood.* 4s. 6d.

Health, and How to Promote it. By Richard McSherry, M. D., President of the Baltimore Academy of Medicine, 12mo. New York. *Appleton.* $1.25.

——, The Public. Suggestions as to the Preparation of District Maps and plans for Main Sewerage, Drainage and Water Supply. With 18 Plans. Roy. 8vo. R. Rawlinson. London. *British Government Publication.* 3s.

Illuminating: A Practical Treatise on the Art. By Marcus Ward, illuminator to the Queen. With 26 Examples of the Styles prevailing at the different Periods, from the Sixth Century to the Present Time; chromographed in facsimile and in outline. Fcap, 4to. London. *Marcus Ward & Co.* 5s.

Lithography: Grammar of Lithography. A Practical Guide for the Artist and Printer in Commercial and Artistic Lithography, Zincography, Photolithography and Lithographic Machine Printing. Edited and revised, with an Introduction, by the Editor of "The Printing Press and Lithographer." Post 8vo. W. D. Richmond. London. *Wyman.* 5s.

Map Drawing; The parallel and meridional system. W. V. Marshall. 4to. New York. *Barnes.* $0.25.

Mathematical Problems. Jos. Wastenholme. 8vo. London. 2d ed. enl. New York. *Macmillan.* $6.00.

Mathematical Tables. James Pryde. New ed. 12mo. Edinburg. *Chambers.* New York, *Worthington.* $1.75.

Municipal Corporations Companion, Diary, Directory, and Year-Book of Statistics for 1879. 8vo. London. *Waterlow.* 5s.

Physics, Practical Physics, Molecular Physics and Sound. (London Science Class Book.) F. Guthrie. 18mo. London. *Longman's.* 1s. 6d.

Physical Forces, new and original theories. H. Raymond Rogers. 12mo. Dunkirk, N.Y. *C. K. Abel & Son.* $0.60.

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Strength of Materials. Wm. Kent. (Science Series No. 41.) 16mo. New York. *Van Nostrand.* $0.50.

Telegraphy. Book for beginners. F. S. Beechey. 8vo. London and New York. *Spons.* $0.60.

Turbine Wheels. On the inapplicability of the Theoretical Investigation of the Turbine Wheel as given by Rankine, Weisbach, Bresse and others, to the Modern Constructions introduced by Boyden and Francis. By Prof. W. P. Trowbridge. 18mo, illustrated. (Science Series No. 44.) New York, *Van Nostrand.* $0.50.

Warming Buildings. Practical treatise on warming buildings by hot water, steam and hot air ventilation, and the various methods of distributing artificial heat, and their

effects on animal and vegetable physiology; [also] an inquiry into the laws of radiant and conducted heat, chemical constitution of coal, and combustion of smoke. C. Hood. 5th ed., enl. 8vo, illus. New York. *Spons.* $4.25.

Woods, Native and Foreign. Les Bois Indigenes et Etrangers : Leur Physiologie, Culture, Production, Qualités, Defauts, Statistique, etc. Par Alph. E. Dupont, Ingenieur des Constructions Navales, et Bouquet de la Grye, Conservateur des Forets. Un Volume in 8°, orné de 162 Gravures. Prix. 12fr.

Year book of facts in Science and the Arts for 1878. J. Mason. 8vo. London. *Ward & Lock.* 2s. 6d.

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From Administration des Ponts et Chausées, Paris :

Annales, January, 1879.

From American Institute of Mining Engineers, Thomas M. Drown, Secretary, Easton, Pa.:

Transactions, Vol. VI. May 1877, to February, 1878.

From Geo. D. Ansley, City Surveyor, Montreal, Canada :

Report of the City Surveyor of Montreal, for 1878.

From Argentine Scientific Society, Don Felix Amoretti, Secretary, Buenos Ayres :

Annals of the Society. December, 1878. January, 1879.

From Austrian Society of Engineers and Architects, Vienna, Austria ;

Zeitschritt. Dr. Wilhelm Finter, Redaktor. Part XII. 1878. Part I. 1879.

From Board of Water Commissioners, Buffalo, N. Y :

Tenth Annual Report of Buffalo City Water Works. Buffalo. 1879.

From Robert Briggs, Philadelphia :

Machines for making Ice, using Sulphurous Acid or Ammonia in the process. Robert Briggs. Philadelphia. 1870.

From W. E C. Coxe, Philadelphia :

Report of the President and Managers of the Philadelphia and Reading Railroad Co. Philadelphia. 1879.

From J. James R. Croes, New York :

Annual Report of the Newark, N. J., Aqueduct Board, for the year ending November 30th, 1878. Newark. 1878,

One Photograph " Mattrass Revetment," on the upper Missouri River in 1878, in charge of S. H. Yonge, Asst. U. S. Civil Engineer.

From Joseph P. Davis, City Engineer, Boston :

Annual Report of the City Engineer of Boston, for 1878.

From Fred. de Funiak, Louisville, Ky.:

Annual Report of the Louisville and Nashville Railroad Co, June 30th, 1878.

Cost of road repairs for six months, ending December 31, 1878. Lou. and Nash., and South and North Ala. Railroads.

Itemized statement of car repairs, and expenses for six months, ending December 31, 1878. Lou. and Nash. and South and North Ala. Railroads.

From Franklin Institute, Philadelphia :

Journal of the Institute for January and February, 1879. Philadelphia. 1879.

From F. U. Farquhar, Rock Island, Ill.:

Annual Report of the Railroad Commissioners of Minnesota, for 1875. J. J. Randall. St. Paul. 1876.

Second Annual Report of the Geological and Natural History Survey of Minnesota. St. Paul. 1874.

Report of the Canal Commissioners of Minnesota, for 1875. St. Paul. 1876.

Second Annual Report of the State Fish Commissioners of Minnesota. St. Paul. 1876.

Statistics of Minnesota, for 1871, 1872, 1873 and 1874.

Annual Report of the Board of Regents of the University of Minnesota. 1872 and 1874.

First, Second, Fourth, Fifth, Sixth and Seventh Annual Reports of the St. Paul, Minn., Chamber of Commerce.

Peat for Domestic Fuel. S. F. Peckham. Minneapolis. 1874.

From Hon. A. A. Haggett, Lowell, Mass.:

Sixth Annual Report of the Lowell Water Board. Lowell. 1879.

From Hon. Abram S. Hewitt, New York;

Our National Inheritence. and how to enjoy it. Abraham S. Hewitt. Washington. 1879. (Copies for distribution.)

From General A. A. Humphreys, Chief of Engineers, U. S. A., Washington, D. C. :

Cost of Lake Survey. Gen. C. B. Comstock. (2 copies.)

Estimates for continuing the improvement of the White and St. Francis Rivers, the l'Anquilla River, and the Buffalo Shoals in White River. Maj. W. H. H. Benyaurd. (2 copies.)

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Reports upon the results of examinations of the Chickasaha, Pascagoula and Flint Rivers. (2 copies.)
Report in relation to removal of the wreck of the schooner Addie Walton, from Delaware Bay. Gen. J. N. Macomb. (2 copies.)
Report upon the harbor at the Delaware Breakwater. Gen. A. A. Humphreys. (2 copies.)
Reports upon proposed improvements in the Delaware, at or near Schooner Ledge. Gen. J. N. Macomb. (2 copies.)
Report on improvement of Illinois River and Illinois and Michigan Canal. Capt. G. J. Lydecker. (2 copies.)
Report on survey of the Kankakee River. Maj. J. A, Smith. (2 copies.)
Report upon Kansas and Arkansas Rivers. Maj. C. R. Suter. (2 copies)
Report upon surveys of Long Island Coast. Gen. John Newton. (2 copies.)
Report in relation to the amount of appropriation necessary to complete the breakwater and piers at the harbor of Michigan City, Ind. Maj. J. A. Smith. (2 copies.)
Preliminary Report on the survey of the Missouri River, from its mouth to Sioux City, Iowa. Maj. C. R. Suter (2 copies.)
Report upon survey of Missouri River at Saint Charles, Mo. Maj. C. R. Suter. (2 copies.)
Report of surveys of North Landing River, Onancock Harbor and Nottaway River, Va., and Pedee, Trent, Neuse. Chowan and Tar Rivers in North Carolina. Capt. C. B. Philips. (2 copies.)
A Report upon the examination of the flats of the Potomac River. Col. T. Lincoln Casey. (2 copies.)
Reports upon the Harbors of San Luis Obispo, Santa Barbara and San Buenaventura, and Humboldt River. (2 copies.)
A Report upon an examination of the Savannah River above Augusta, Ga. Gen. Q. A. Gillmore. (2 copies.)
Results of an examination made of the Missouri River at and near its junction with the Kansas River, and the estimated cost of its improvement. Maj. C. R. Suter. (2 copies.)
The Work upon Hoard's Rocks, Monongahela River. Col. Wm. E. Merrill. (2 copies.)

From Institution of Civil Engineers, publications edited by James Forrest, Secretary, London, as follows :

Abstracts of Papers in Foreign Transactions and Periodicals. Vol. LV. Session 1878-9. Part 1.
Engineering Progress in Foreign Countries. Vernon-Harcourt, Clark, Bauerman and Higgs.
Harbor and Dock Works;
(1.) The Avonmouth Dock. J. Mackensie.
(2.) The River Lagan and Harbor of Belfast. Thomas R. Salmond.
(3.) Whitehaven Harbor. John. E. Williams.
On the Heating and Ventilating Apparatus of the Glasgow University. W. W. Phipson.

From the Institution of Mechanical Engineers, Walter R. Browne, Secretary, London :

Proceedings of the Institute, July 28th and 29th, 1868.

From Wm. Ripley Nichols, Boston :

Chemical Examinations of Sewer Air. Prof. Wm. Ripley Nichols, Boston. 1879.

From Edward P. North, New York ;

Official Catatogue of the United States Exhibitors at the Paris Universal Exposition. London, 1878.

From the North of England Institute of Mining and Mechanical Engineers, Theo. Wood Bunning, Secretary, Newcastle-on-Tyne, England :

Transactions of the Institute, December, 1878.

From Ernest Pontzen, Paris ;

Maison Spéciale pour l'application de la pression Hydraulique a toute industrie. H. Thomasset. Paris, 1878.

From W. N. Radenhurst, Rochester, N. Y. :

Report of State Engineer for 1878. Horatio Seymour, Jr. Albany. 1879.

From John Reid, Paterson, N. J. :

Two Photographs, Iron Work Construction, Seventh Regiment Armory, New York City, C. W. Clinton, Architect.

From the Publishers, Revue Général des Chemins de fer. Edgar Monjean, Secretary, Paris :

Revue Général des Chemins de fer. December, 1878.

From William Rotch, Fall River, Mass.:

Fifth Annual Report of Watuppa Water Board. Fall River. 1879.

From the Royal United Service Institution, Capt. B. Burgess, Secretary, London :

Journal of the Institution, No. XCVIII, Vol. XII.

From John Russell, San Francisco:

Municipal Reports of San Francisco. 1877-8.

From Wm. B. Sherman, New Bedford, Mass.;

Ninth Annual Report of the Acushnet Water Board. New Bedford. 1878.

From Société des Ingénieurs Civils, Paris:

Memoires. September and October, 1878.

From R. H. Thurston, Hoboken, N. J.:

Address before the American Association for the Advancement of Science, at the meeting held in St. Louis, August, 1878. Prof. R. H. Thurston. Salem, Mass. 1878.
Friction and its Laws, as determined by recent experiment. Prof. R. H. Thurston. Salem Mass. 1878.
New determinations of the coefficients of Friction of Lubricated Journals. and on the law governing such friction. Prof. R. H. Thurston. Philadelphia. 1878.

From George E. Waring, Jr., Newport, R. I.;

Irvington Sanitary Survey. An examination as to local causes of fever and ague on the

east bank of the Hudson River from Dobb's Ferry to Tarrytown, with recommendations for improvement. Geo. E. Waring, Jr. New York. 1879.

From Joseph M. Wilson, Philadelphia:
Notes on the Internal Improvements of Pennsylvania, and Reminiscences of the first railroad over the Allegheny Mountains. W. Hasell Wilson and Solomon W. Roberts. Philadelphia. 1879.

From Wilson Brothers & Co., Philadelphia:
Two plates of Bridge over Pennsylvania R. R. at Belmont Avenue, Philadelphia.
Two plates of Bridge over Pennsylvania R. R. at Fortieth Street, Philadelphia.
Two plates of Bridge over Pennsylvania R. R. at Forty-first Street, Philadelphia.
Two plates of Span No. 1 of the Morrisville Bridge, New York Division, Pennsylvania R.R.
Two plates of Suspension Bridge (Ordish's System) over the Pennsylvania R. R., Forty-first Street, Philadelphia.
Two plates of Jersey City Station, Pennsylvania R. R.
Two plates of Passenger Station, Baltimore and Potomac R. R.
Two plates of West Philadelphia Station, Pennsylvania R. R.

From F. Leypoldt. New York:
The American Catalogue, Vol. I. Authors and Titles. Part 2. Edwards—Lennox.
The Library Journal, Nos. 1 and 2, Vol. IV.
The Library Journal, Index to Vol. III, March. 1878, December, 1878.
The Title slip Registry, Vol. I, Nos. 1 and 2.

ANNOUNCEMENTS.

The Eleventh Annual Convention of the Society will be held at Cleveland, June 17th, 1879. Announcement as to the details of programme and proceedings will be issued in a short time.

Copies of the Speech made in Congress by Hon. Abram S. Hewitt upon the subject of the Public Lands and their Surveys have been kindly sent to the Society by the author and mailed to the members.

The following resolution was adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications:

Whereas, the metric system of weights and measures is now extensively used abroad, and whereas it is desirable that the relation of the units of differing systems be made familiar to all by comparison:

Resolved, That members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimensions by the metric system, in connection with those of the system in general use.

The House of the Society is at 104 East Twentieth street, one door from Fourth avenue, and near the southwest corner of Gramercy Park. It is open from nine o'clock A.M. to five o'clock P.M. each business day, except Saturday, when it is closed at three o'clock P. M.

The Library and Conversation Rooms will also, for the present, be open every *Thursday evening*, from 7½ to 10 P. M. Members are invited to avail themselves of the opportunities afforded on Thursday evenings both for consultation of books and periodicals and for conversation.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

Date of Election.

Egleston, Thomas.....Professor of Mineralogy and Metallurgy, School of Mines, Columbia College, 35 West Washington Square, New York.....March 5th, 1879.

Date of Election.

OSGOOD, JOSEPH O.....(Elected Junior May 3d, 1876), Division Engineer Pueblo and Arkansas Valley Railroad, Cañon City, Colorado.....March 5th, 1879.

JUNIOR.

ALLEN, JAMES P.....Civil Assistant Engineer U. S. Corps of Engineers, care of Maj. F. U. Farquhar, Rock Island, Ill.....March 5th, 1879.

CHANGES AND CORRECTIONS.

MEMBERS.

AUCHINCLOSS, WILLIAM S. 200 West Logan Square, Philadelphia, Pa.

CLARKE, THOMAS C.....71 Broadway, Room 72, New York.

FINK, RUDOLPH.....General Manager, Memphis and Little Rock Railroad, Little Rock, Ark.

FLINT, EDWARD A.....11 Tremont Bank Building, Boston, Mass.

NICHOLS, OTHNIEL F. ...Box 229, Westerly, Rhode Island.

ROBERTS, W. MILNOR....Care of O. C. James, Caixa N. 721, Rio de Janeiro, Brazil.

SMITH, HAMILTON, JR....Civil and Mechanical Engineer, Room 24, 320 Sansom st., San Francisco, Cal.

VAN BUREN, JOHN D., JR..10 West Thirtieth st., New York.

JUNIOR.

STAATS, ROBERT P.....169 West Twelfth st., New York.

DECEASED.

CRAVEN, ALFRED W.....President of the Society from November 3, 1869, to November 1, 1871...March 27th, 1879.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. V.—February, 1879.

[Up to May 15th, 1879.]

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

April 16th, 1879.—The Society met at 8 p. m. Past President George S. Greene, in the chair.

A paper, entitled "The Construction and Maintenance of Roads," by Edward P. North, was read by the author.

The discussion of the paper was postponed to a future meeting.

May 7th, 1879.—The Society met at 8 p. m. Mr. Charles Macdonald in the chair.

The ballot for membership was canvassed, and the following candidates declared elected:—As Members—Daniel P. Bruner (elected Junior, September 6th, 1876), Harrisburg, Pa.; Thomas G. Dabney, United States Engineer in charge of Harbor Works, Vicksburgh, Miss.; Henry B. Richardson, Assistant State Engineer, Louisiana Board of State Engineers, St. Joseph, La.; Max E. Schmidt, Chief Assistant Engineer South Pass Jetty Works, Port Eads, La. As Associate—Percival Roberts, Jr., Pencoyd Iron Works, Philadelphia, Pa.

On motion of Theodore Cooper, the minutes of the meeting of the Society of April 2d (Vol. V, p. 5, seventh line from bottom), were amended by inserting as follows: "Mr. Cooper withdrew the motion, as he considered the expression of the members during the discussion was sufficiently expressive without bringing the result to a vote; and not being aware of the action of the Board of Direction until after the reso-

lution had been offered, he did not wish to develop by a vote an expression of the opinion of the meeting in opposition to the action of the Board."

The action of the Board of Direction in reference to notices of arrears of dues and as to publication of Proceedings and Transactions was reported. (See Minutes of Board of Direction of April 30th, below.)

The following preamble and resolution were then discussed and passed :

Whereas, Every possible effort should be made to increase the sphere of usefulness of the Society, and to enlarge its membership as well as to promote active intercourse between all its members, therefore, be it

Resolved, That the following suggestions and such others as may be submitted, be printed and distributed among the members, with the request that they shall favor the Secretary as soon as possible with their opinions, as well as with such other suggestions as they may wish to offer, so that action upon the same may be taken at the next convention.

SUGGESTIONS.

1st. That provision be made for the holding, in addition to the annual convention, a number of general meetings in various cities in each year, for professional intercourse.

2d. That papers be annually invited from members or other persons upon subjects of general engineering interest, to be specified by the Board of Direction.

3d. That a system be established to award special recognition for the best papers contributed each year.

4th. That present members be encouraged to propose worthy persons for new members, associates, and fellows.

5th. That to promote the discussion of papers, advance copies be issued to such members or other persons as may be specially qualified to take part in the same, or to members applying for them in order to take part in the discussion.

6th. That members be encouraged to make use of the facilities of the Society in New York for obtaining professional information.

7th. That the Library Committee be requested to report whether some plan may not be adopted to enable members living away from New York to consult the books of the Library, under proper regulations to ensure their return and to prevent injury.

8th. That suggestions be invited from members as to the feasibility of adopting some plan of affiliation with local engineers' clubs in other cities.

9th. That the desirability be discussed of appointing Research Committees, whose duties shall be to collect the results of existing experiments on any subject, and to suggest what further experiments are necessary, and also to collate such professional papers as may have been published elsewhere.

OF THE BOARD OF DIRECTION.

JANUARY 3D, 1879.—Applications for membership were considered. The filing of the annual certificate required by statute was reported by the Secretary. Appropriations were made.

FEBRUARY 5TH, 1879.—Applications for membership were considered, and financial business transacted.

MARCH 6TH, 1879.—Applications for membership were considered. Appropriations were made.

APRIL 2D, 1879.—Applications for membership were considered. Financial business was transacted. A resolution was adopted as to publications of Transactions and Proceedings (printed in Minutes of the Society for April 2d, 1879, Proceedings, Vol. V, page 5).

APRIL 30TH, 1879.—Applications for membership were considered. The Treasurer reported the number of members in arrears for dues, and the amount owing to the Society by its members. The following resolution was passed :

Resolved, That the Secretary be directed to notify all members in arrears that unless the dues for the current Society year, beginning November 6th, 1878, are paid before November 5th, 1879, they will cease to be members.

Also, that members who are in arrears for more than the dues for the current year, be notified that their dues for years previous to the current year are still to be paid, and that payment of the same will be required, unless good reason to the contrary, in compliance with the provisions of Article XXXII, of the Constitution, be assigned before November 5th, 1879.

The resolution referred to the Board at the meeting of the Society of April 2d, and the former action of the Board on the subject of publication of the Transactions and Proceedings, were considered, and the following resolution was adopted :

That business proceedings are not to be reported for the public press. Abstracts of the papers read and discussions thereon, giving the general tenor of the papers, etc., may be published.

Appropriations were made.

LIST OF NEW BOOKS ON

ENGINEERING AND TECHNOLOGY.

Alphabets, Prang's Standard ; Designs for titles, colored initials, borders, compass points, topographical signs, the State Arms of the Union, etc. Especially adapted for the use of sign-painters, engravers, illuminators, architects and civil engineers. 42 plates, 14 in color. Boston. *Prang & Co.* $5.00

Art ; Illustrations of the History of —. A series of above 2 000 woodcuts, selected, by permission, from the works of Kugler, Lubke, Burckhardt, Overbeck, Dohme, C. Von Lutzow, Falke, Woltmann, La roix, etc. Chronologically arranged. Authorized American edition, published under the supervision of S. R. Koehler. Boston. *Prang & Co.*

The complete work will consist of the following series :

I. Architecture, Sculpture, and the Indus-

trial Arts among the Nations of Antiquity. 39 plates. $1.50.

II. Architecture and Sculpture of the Early Christian, Romanesque, and Gothic Periods. Architecture and Ornamentation of the Mohamedan Nations. 57 plates. $2.25.

III. Architecture and Sculpture of the Renaissance Period and of the Modern Times. 48 plates. $2.00.

IV. The Industrial Arts among the Oriental Nations and the Nations of Europe, from the Middle Ages down to Modern Times. 42 plates. $1.75.

V. The History of Painting, from the Time of the Egyptians to the Close of the 18th Century. 60 plates. $2.50.

Size of plate 17 × 12. Each of these series is complete in itself, and is sold separately.

Astrolabe; On Champlain's —, lost June 8th, 1613, found August, 1867; considered in solution of an obscurity in his journal of first voyage up the Ottowa; and the great antiquity of astrolabes, and origin of their graduation. 24 p., maps and phot. A. J. Russell, 8vo. Montreal. *Dawson Bros.* $0.50.

Building Construction; Notes on —. Part 3. Materials. 8vo. London. *Rivingtons.* 21s.

Buildings for Laboring Classes: the need, and way to meet it on strict commercial principles, in New York and other cities. New York. *Putnams.* 8vo. $0 30.

Canal Reminiscences; recollections of travel in the old days on the James River and Kanawha Canal. G. W. Bagley. Richmond, Va 12mo., *West, Johnson & Co.* $0 20.

Carpenters' and Builders' Guide. L. D. Gould. Rev. Ed., 8vo illus. New York. *Bicknell & Comstock.* $3.00.

Circle: The System of Calculating Diameter, Circumference, Area, and Squaring the Circle; with tables and information. James Morton. Philadelphia. *Claxton, Remsen & Haffelfinger.* $1 00.

Club Directory: A General Guide or Index to the London and County Clubs, and those of Scotland, Ireland and British Colonial Possessions; together with the English Clubs in Europe, the United States, and elsewhere throughout the world; their Constitution, Amount of Entrance Fee and Subscription. Names of Trustees and Secretaries, together with other useful information; the whole interspersed with amusing and interesting Anecdotes collected with some amount of labor from various sources. G. J. Ivevy London 8vo. *Harrison.* 5s

Color-sense; its origin and development. Grant Allen Boston. 8vo. *Houghton, Osgood & Co.* $3.50.

Color, the theory of —, in its relation to Art and Art industry. W. Von Bezold. Trans. by S R. Koehler. Boston. 12mo, illus. and plates. *L. Prang & Co.* $5 00.

Drainage. Hints on House Drainage, for owners, occupants and builders. H. Ough. 8vo illus. *Spons.* London. 6d. New York 20cts

Draining for profit and draining for health. G. E. Waring, Jr. 12mo, illus., 2d ed., rev. and enl. New York. *Orange Judd & Co.* $1.50.

Education as a Science. By Alexander Bain, LL.D. Number 25 of "The International Scientific Series." 12mo. New York. *Appletons.* $1.75.

Healthy Houses. Fleming Jenkin. Adapted to American conditions, by G. E. Waring, Jr. New York. *Harpers.* 25cts.

Health Primers. No. 5. Personal appearance in health and disease. Sidney Coupland, M D. No. 6. Baths and Bathing. New York. 16mo. *Appletons.* Each 40cts.

Lighthouses and Lightships. A Descriptive and Historical Account of their Mode of Construction and Organization. W. H. D. Adams. Illus. from Photographs, &c. Post, 8vo. London. *Nelson & Sons.* 3s. 6d.

Locomotive Engines. A Historical Sketch and Description, by G. D. Dempsey, C. E. With large Additions, treating of the Modern Locomotive, by D. Kinnear Clark, M.I.C.E. Weales Series. London. *Crosby Lockwood.* 3s. 6d.

Mechanical Engineering; Tables of principal speeds occurring in mechanical engineering, expressed in metres, in a second, by P. Keerayeff, tr. by Sergius Kern. London, 8vo. *Spons.* 6d.

Mechanics' Reference Book; Calverts; Practical and Entertaining Information for Handicraftsmen: Being the whole Series of Calvert's Mechanics' Almanack, from the Commencement, 1874 to 1879, inclusive. Also a Practical Treatise on Decimal Arithmetic, Tables, &c., to which is added a specially compiled List of Technical Books. London. Post. 8vo. J. Heywood. 3s 6d.

Pebbles, Alpheus Hyatt (Guides for Science-teaching No. 1). Boston. *Ginn & Heath.* $0.15.

Pennsylvania Railroad in its engineering aspect. Jas. Dredge. New York. 4to. *Wiley.* $15 00.

Railroad Accidents; their causes and prevention. Charles Francis Adams. New York. 12mo. *Putnams.* (Announcement)

Railroad Securities, A Treatise on the Law of Railroad and other Corporate Securities, including Municipal Aid Bonds. Leonard A. Jones. Boston. 8vo. *Houghton, Osgood & Co.* $6.50.

Rocks, The Study of Rocks. An Elementary Text-book in Petrology By Frank Rutley, of the English Geological Survey. New volume in "Text-Books of Science Series." 16mo. illus. New York. Appletons. $1.75.

Road Locomotives. A summary of the Roads Locomotive Acts, 1861, 1865 and 1878, in Force in England and Scotland. Compiled for the Use of Road Locomotive Engine Proprietors and Users. 18mo, pp. 24, *Groom* (Thetford) *Simpkin.* London. 6d.

Road Maintenance: The maintenance of Macadamise roads. Thomas Codrington. London 8vo. *Spons.* 6d.

Rule: Spiral Slide — equivalent to a straight slide rule 83 feet 4 inches long, or a circular rule 13 feet 3 inches in diameter (patent). By G. Fuller. Fcap, 8vo. *Spons.* New York. $0.20.

Sewage Poison; how to avoid it in the cheapest and best way. Ed. T. Blake. London. 8vo. *Hardwicke & Bogue,* 1s.

Steam Engine, Marine ——— ———. Robert Murray. (Weale's Series.) New ed. 12mo. *Crosby Lockwood.* 3s.

——— ——— Catechism of the Marine Steam Engine, for the use of engineers, firemen, mechanics. By Emory Edwards. Illus by eng. of most modern engines. 12m. Philadelphia. *H. C. Baird.* $2.00.

Trusses and Arches analyzed and discussed by graphical methods. In three parts. Part II: Bridge trusses, single, continuous and draw spans; single and multiple system; straight and inclined chords. C. E. Greene. New York. 16mo. Plates. *Wiley*. $2.50.

Tunnelling in Heavy Ground, for Railways. C. T. Gupper. London. 8vo. *Spons*. 7s. 6d.

Water; On the quantity and quality of water supplied to London during 1878 Charles M. Tidy. London. 8vo. *Churchill*. 6d.

Water Pipes; The kitchen boiler and water pipes: their arrangement and management, their treatment during frost, and how to avoid explosions. By H. Grimshaw. 8vo. *Spons*. London. 1s. New York. $0.40.

ANNOUNCEMENTS.

The Eleventh Annual Convention of the Society will be held at Cleveland, beginning Tuesday, June 17th, 1879.

Sessions for the consideration of professional subjects, and one for the transaction of business will be held.

The details of the programme will be announced as soon as determined by the local committee.

The following is a list of topics to be considered with reference to papers published in Transactions during the preceding year:

American Engineering at International Exhibitions.

CLXXIV. American Engineering as illustrated at the Paris Exposition of 1878. George S. Morison, Edward P. North and John Bogart.

Bridges.

——— Discussion of Paper CXL. The Determination of Stresses in the Eye-Bar Head. De Volson Wood. Vol. VII, page 189.

——— Discussion of Papers CXLIV and CXLIX. Relative Quantities of Material in Bridges of different kinds, of various heights. William H. Searles. Vol. VII, page 192.

Cements.

——— Discussion on Cements. Don J. Whittemore. Vol. VII, page 274.

——— Discussion on Cements and Strength of Bricks. F. Collingwood. Vol. VII, page 280.

Foundations.

CLXXII. The use of Compressed Air in Tubular Foundations, and its application at South Street Bridge, Philadelphia, Pa. D. McN. Stauffer.

Hydraulics.

CLX. On the Cause of the Maximum Velocity of Water flowing in Open Channels being below the Surface. James B. Francis.

CLXI. The Flow of Water in Pipes under Pressure. Charles G. Darrach.

——— Discussion on the Cause of the Maximum Velocity of Water flowing in Open Channels being below the Surface, and also on the Flow of Water in Pipes under Pressure. Theo. G. Ellis, C. E. Emery, Clemens Herschel, De Volson Wood and John T. Fanning. Vol. VII., page 122.

CLXVII. Distribution of Rain-fall during the great storm of October 3d and 4th, 1869. James B. Francis.

CLXVIII. The Gauging of Streams. Clemens Herschel.

CLXXV. The Flow of Water in Small Channels, after Ganguillet and Kutter, with Kutter's Diagram modified, and Graphical Tables with special reference to Sewer Calculations. R. Hering.

Masonry.

CLXX. Brick Arches for Large Sewers. R. Hering.

——— Discussion on Brick Arches for Large Sewers. E. S. Chesbrough, W. Milnor Roberts, R. Hering and F. Collingwood. Vol. VII., page 258.

CLXXI. Fall of Western Arched Approach to South Street Bridge, Philadelphia, Pa D. McN. Stauffer.

——— Discussion on Nomenclature of Building Stones and Stone Masonry. J. Foster Flagg. J. J. R. Croes, J. P. Davis, F. Collingwood, J. Veazie and E. P. North. Vol. VII., page 284.

Metals.

CLXIII. On a newly discovered relation between the Tenacity of Metals and their resistance to Torsion. Robert H. Thurston.

CLXIV. Observations on the Stresses developed in Metallic Bars by Applied Forces. Theodore Cooper.

Preservation of Timber.

CLXXVI. The Permanent Way of Railways in Great Britain and Ireland, with special reference to the use of Timber, preserved and unpreserved. Compiled from information received from Engineers

in charge of those railways. John Bogart.

RAILROADS.

CLIX. On the Theoretical Resistance of Railroad Curves. S. Whinery.

—— Discussion on the Resistance of Railroad Curves. O. Chanute, Chas. E. Emery, E. Yardley, E. P. North, C. L. McAlpine, F. Collingwood and Wm. H. Paine. Vol. VII, page 97.

CLXVI. Reminiscences and Experiences of Early Engineering Operations on Railroads, with especial reference to Steep Inclines. W. Milnor Roberts.

—— Discussions on Inclined Planes for Railroads. O. Chanute and William H. Paine. Vol. VII., page 216.

RIVERS AND HARBORS.

CLXII. The South Pass Jetties. Descriptive and Incidental Notes and Memoranda. E. L. Corthell.

—— Discussions on the South Pass Jetties. Charles W. Howell, E. L. Corthell, C. Shaler Smith, J. Foster Flagg. Vol. VII, page 159.

CLXIX. The Dangers threatening the Navigation of the Mississippi River and the Reclamation of its Alluvial Lands. B. M. Harrod.

STEAM ENGINES.

CLXV. Cushioning the Reciprocating Parts of Steam Engines. John W. Hill.

—— Discussion on Steam Engine Economy, J. Foster Flagg and E. D. Leavitt, Jr. Vol. VII, page 194.

SUBMARINE TELEPHONY.

CLXXIII. Submarine Telephoning. Chas. Ward Raymond.

In addition to the above papers, it is expected that the following subjects will be presented by papers printed previous to the date of the Convention, or read at its meeting:

Engineering Questions involved in the Development of Electric Lighting. Stephen Chester.

Gelatine Dynamite and High Explosives. Julius H. Striedinger.

Lighthouse Construction. J. G. Barnard.

Memoir upon the Construction of the Minots Ledge Light. B. S. Alexander.

The Construction and Maintenance of Roads. Edward P. North.

The Resistances of Railway Rolling Stock. A. M. Wellington.

The Railroad Crossing of the Allegheny Mountain. Moncure Robinson.

Notes on Early Railroad Engineering. Ashbel Welch.

Remarks on the Causes of Fall of the Western Arched Approach to South Street Bridge, Philadelphia, Pa. J. G. Barnard.

Parabolic Arches in Masonry. W. A. G. Emonts.

Notes on the Foundations of Piers of the East River Bridge. F. Collingwood.

Experiments with Cements and appliances for testing. Alfred Noble.

Comparison of Standard Measures, English, French and United States. Arthur S. C. Wurtele.

The Construction of Concrete Blocks at the end of the South Pass Jetties. Max E. Schmidt.

Notes as to construction and operation of the Railroad over the Raton Mountains, Col., and the construction and performance of the Locomotives thereon. James D. Burr.

Design and Construction Tables for Egg-shaped Sewers. Cyrus G. Force, Jr.

Members of the Society are earnestly requested to furnish information or memoranda upon any of the subjects referred to. They are also invited and expected to take part in the discussions either in person or by sending to the Secretary notes for presentation.

In either case, it will assist the Committee in arranging the details for sessions of the Convention, if Members expecting to take part in the discussions will notify the Secretary at once to that effect.

Excursions upon the Lake and by rail from Cleveland are contemplated, and the arrangements for them are in progress.

Invitation to visit Pittsburg and the Government Works for the improvement of the river at that place (Davis Island Dam), has been extended by James H. Harlow, Member of the Society.

Please notify the Secretary whether you will visit Pittsburg, and whether you wil present a paper or take part in the discussions at Cleveland.

The Title Page and Contents of Vol. VII, of the Transactions, and Title Page and Index of Vol. IV of the Proceedings, are issued with this number.

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LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

Date of Election.

BELL, JAMES E.....Superintendent City Water Works, Cincinnati, Ohio..... .....March 5th, 1879.

BRUNER, DANIEL P.....(Elected Junior, September 6th, 1876) 13 North Third street, Harrisburg, Pa. .....May 7th, 1879.

ASSOCIATE.

GORDON, ALEXANDER... General Manager Niles Tool Works, Hamilton, Ohio.....March 5th, 1879.

CHANGES AND CORRECTIONS.

MEMBERS.

BROWN, CHARLES O .... 52 Wall street, Room 27, New York.

BRUSH, CHARLES B.....13 Newark street, Hoboken, N. J.

BUCK, L. L.....Engineer Suspension Bridge, Niagara Co., N. Y.

CHESTER, STEPHEN .....5 and 7 Dey street, New York.

DURHAM, C. WHEELER...109 Dearborn street, Chicago, Ill.

GARDNER, G. CLINTON...Manager Troy, Greenfield and Hoosac Tunnel Railroad, Greenfield, Mass.

GRANT, WILLIAM H.....Chief Engineer New York City and Northern Railroad and Yonkers Rapid Transit Railway, 3 Broad street, New York.

HALL, G. THOMAS.. ....Division Engineer Metropolitan Elevated Railroad, 71 Broadway, New York.

HARRIS, ROBERT L.... .Consulting Engineer, Boston, Hoosac Tunnel and Western Railroad, North Adams, Mass.

MERIWETHER, NILES.....Memphis, Tenn.

NICOLLS, WILLIAM J.,....Editor Railway Record, 5 Post Office avenue, Baltimore, Md.

PARKHURST, H. W.....Topeka, Kansas.

PETTIT, HENRY.....209 South Third street, Philadelphia, Pa.

SEARS, ALFRED T.....Ingeneiro de Estado, Peru, Chimbote, Peru, via Panama.

SEDGWICK, THOMAS S.....Washington, D. C.

TURNER, EDMUND.....Engineer, Logansport, Crawfordsville and Southwestern Railroad, Crawfordsville, Ind.

WALLING, HENRY F.....Marietta, Ohio.

ASSOCIATES.

BREVOORT, HENRY L.....206 Broadway, New York.

FORD, ARTHUR L..... Civil Engineer, Corinto, Nicaragua.

JUNIORS.

BLAND, JOHN C.....Office Supervising Architect, Treasury Building, Washington, D. C.

HAYES, EDMUND.....52 Wall street, New York.

HORTON, SANFORD.....Division Engineer, Atchison, Topeka, and Santa Fé Railroad, Wichita, Kansas.

KENNEDY, JAMES C... ...Engineer's Office, Water works, Ottawa, Canada.

MACY, ARTHUR.....Kings Mountain Mine, Kings Mountain, N. C.

FELLOW.

TAYLOR, WILLIAM J.....Chester, N. J.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. V.—March, April, May, 1879.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

May 21st, 1879.—The Society met at 8 P. M. Thomas C. Clarke in the chair.

A paper by J. James R. Croes, entitled "The Loss of Water in Flowing in Open Earth Channels, was read by the author, and discussed by Messrs. Dresser, Emery, Owen, Searles, Striedinger, L. B. Ward and Worthen.

Note.—At the meeting of the Society of May 7th, 1879, the following preamble and resolutions were passed :

Members of the Society are requested to favor the Secretary with their opinions on the subjects referred to, and with such other suggestions as they may wish to offer, sending the same in time for presentation at the Convention at Cleveland on June 17th, next.

Whereas, Every possible effort should be made to increase the sphere of usefulness of the Society, and to enlarge its membership as well as to promote active intercourse between all its members, therefore, be it

Resolved, That the following suggestions and such others as may be submitted, be printed and distributed among the members, with the request that they shall favor the Secretary as soon as possible with their

opinions, as well as with such other suggestions as they may wish to offer, so that action upon the same may be taken at the next convention.

Suggestions.

1st. That provision be made for the holding, in addition to the annual convention, a number of general meetings in various cities in each year, for professional intercourse.

2d. That papers be annually invited from members or other persons upon subjects of general engineering interest, to be specified by the Board of Direction.

3d. That a system be established to award special recognition for the best papers contributed each year.

4th. That present members be encouraged to propose worthy persons for new members, associates, and fellows.

5th. That to promote the discussion of papers, advance copies be issued to such members or other persons as may be specially qualified to take part in the same, or to members applying for them in order to take part in the discussion.

6th. That members be encouraged to make use of the facilities of the Society in New York for obtaining professional information.

7th. That the Library Committee be requested to report whether some plan may not be adopted to enable members living away from New York to consult the books of the Library, under proper regulations to ensure their return and to prevent injury.

8th. That suggestions be invited from members as to the feasibility of adopting some plan of affiliation with local engineers' clubs in other cities.

9th. That the desirability be discussed of appointing Research Committees, whose duties shall be to collect the results of existing experiments on any subject, and to suggest what further experiments are necessary, and also to collate such professional papers as may have been published elsewhere.

LIST OF NEW BOOKS ON

ENGINEERING AND TECHNOLOGY.

Alphabets adapted to the use of Architects, Engineers, Engravers, &c. Dan. T. Ames. New York. 12mo. *Bicknell & Comstock.* $1.50.

Bridge Building, Girder Making and the Practice of Bridge Building in Wrought Iron. Illustrated by Examples of Bridges, Piers and Girder Work, &c., constructed at the Skerne Iron Works, Darlington. By Edward Hutchinson, Mem. Inst. M. E. 35 Plates, demy 8vo. London and New York. *Spons.* $4.25.

Coal, Practical treatise on Combustion of Coal, incl. descriptions of various mechanical devices for the economic generation of Heat by the Combustion of Fuel, whether Solid, Liquid or Gaseous. W. M. Barr. Indianapolis. 8vo, illus. *John Bros.* $2.50.

Color Blindness; its Dangers and its Detection. B. Joy Jefferies, M. D. Boston. 8vo. *Houghton, Osgood & Co.*

Drafting Instruments and Operations; in 4 Divisions: 1, Instruments and Materials; 2, Fundamental Operations; 3, Plane Problems and Practical Exercises; 4, Elements of Taste in Geometrical Drawing: Text-Book for Schools, and Artisans' Classes, and for Self-instruction. S. E. Warren. New York, 2d ed. rev. and enl. 8vo, plates. *Wiley & Son.* $1.25.

Electric Lighting and its Practical Application; with Results from Existing Examples. J. N. Schoolbred. London, 8vo, illus. *Hardwicke & Bogue.* 5s.

English Army; its Past History, Present Condition and Future Prospects. Major Arthur Griffiths. 12mo. *Cassell, Petter & Galpin.* New York. $5.00.

Gas Measurement. The serious loss and inconvenience to gas companies and the public, caused by the freezing and inaccuracy of wet meters. George Glover. London. 8vo. *Spons.* 1s.

Geometry; Elements of Co-ordinate —, in three parts: 1, Cartesian Geometry; 2, Quaternions; 3, Modern Geometry; and an Appendix. De Volson Wood. New York. 8vo. *Wiley & Sons.* $3.00.

Mechanism; the Elements of Practical ——. T. Baker. London. Weales' Series. 6th ed. 12mo. *Crosby Lockwood.* 2s. 6d.

Military Engineering. Instruction in — —, Miscellaneous. Compiled at the School of Military Engineering, Chatham. Vol. I. (Part 5). 2d ed. London. Post 8vo. *British Govt. Pub.* 3s. 6d.

Military Map Making. Captain Holdich. London. 8vo. *W. Mitchell.* 1s.

Quantities and Measurements. A. C. Beaton. London. Weales' Series. 5th ed. 12mo. *Crosby Lookwood.* 1s. 6d.

River Shannon. Paper on the — —; its Present State, and the Means of Improving the Navigation and the Drainage; with Discussion thereon, before Section G, British Association, Dublin, 1878. By James Lynam, C. E. London. 8vo. *P. S. King.* 1s. 6d.

Rivers Conservation. Address of E. Easton, C. E., and papers read before the British Association at Dublin. 1878. London. 8vo. *P. S. King.* 2s. 6d.

Royal Engineers. Professional Papers of the Corps of — —. Vol. 2. Occasional Papers, 1878. 8vo. Plates. *Chatham Royal Engineer Institute.* 12s.

Sanitary Work in the Smaller Towns and in Villages. Charles Slagg. London. Weales Series. 12mo. *Crosby Lockwood.* 2s. 6d.

Slide Rule, The Carpenter's: Its History and Use. Containing Instructions for the Measurement of al kinds of Boards and Planks, Timber in the Round or Square, Glazier's Work and Painting, Brickwork, Paviour's Work, Tiling and Slating, the Measurement of Vessels of various shapes, the Wedge, Inclined Planes, Wheels and Axles, Levers, the Weighing and Measurement of Metals and all Solid Bodies, Cylinders, Cones, Globes, Ship Carpenter's Eight Square Lines, the Measurement of Circles, and a Comparison of French and English Measures, with much other information useful to Builders, Carpenters, Bricklayers, Glaziers, Paviours, Slaters, and other Mechanics. Now first printed, in a complete form, at a moderate price. Fcap. 8vo, sd., pp. 32. *Ribone & Sons* (Birmingham). 3d.

Steam Engines. Pocket Book on Compound Engines. N. P. Burgh. London. 16mo. *Burgh.* 7s. 6d.

Table Book. Molesworth's Pocket Book of Useful Formulæ and Memoranda, for Civil and Mechanical Engineers. With a valuable Contribution on Telegraphs, by R. S. Brough and Paget Higgs. 19th ed. 32mo, *Spons.* 6s.

Thermodynamics. Rob. E. Baynes. New York. 12mo. *Macmillan.* $2.75.

Universal Graphical Computing Table, enabling anybody without calculation and at sight to multiply or divide any two numbers: to find 2d, 3d or 5th power of any number; to extract the 2d, 3d or 5th root of any number; to obtain the circumference or area of any circle; to obtain the volume of any sphere, or to multiply or divide by the sine, cosine, tangent or co-tangent of any arc; to reduce feet to metres or metres to feet. Invaluable to Engineers in making estimates; invaluable in preparing percentages or reducing statistics. Error of computation in all cases less than half of one per cent. Handsomely printed on Bristol Board 18 x 19 inches, and accompanied by a small volume of Text containing directions for use and valuable tables. By Lieut. Wm. H. Bixby. *Wiley & Sons.* New York. $0.75.

ADDITIONS TO

LIBRARY AND MUSEUM.

From Administration des Ponts et Chausées, Paris:

Annales. March, 1879.

From American Chemical Society, P. Cassamajor, Secretary, New York:

Journal of the Society, Vol. 1, Nos. 1-3.

From American Institute Mining Engineers, Thomas M. Drown, Secretary, Easton, Pa.:

Proceedings of the Baltimore Meeting, February, 1879.

The Bradford Oil District of Pennsylvania. Chas. A. Ashburner.

The Water Supply at the Bessemer Steel Works of the Edgar Thomson Steel Company, Limited. P. Barnes.

The Lake Superior Copper Rocks in Pennsylvania. J. F. Blandy.

The Great Blast at Glendon. Ellis Clarke, Jr.

An Improved System of Cornish Pitwork. Ellsworth Daggett.

Note on the determination of Silicon in Pig Iron and Steel. Dr. T. M. Drown.

Indicator Cards from a Water-pressure Blowing Engine, with a note on a proposed improvement in such engines. Frank Firmstone.

The manufacture of Soda by the Ammonia process. O. J. Heinrich.

The Perntot Furnace. A. L. Holley, LL D,

The United States Testing Machine at Watertown Arsenal. A. L Holley, LL.D.

The Coal and Iron of the Hocking Valley, Ohio. T. Sterry Hunt, LL.D.

A Method of Rolling Steel or Iron Eye Bars. Charles Macdonald.

On the Classification of Original Rocks. Thomas Macfarlane.

Phosphorus in Coal. A. S. McCreath.

A Catalogue of Official Reports upon Geological Surveys of the United States and Territories and of British North America. F. Primo, Jr.

From Argentine Scientific Society, Don Felix Amoreti, Secretary, Buenos Ayres:

Annals of the Society. March and April, 1879.

From Association of Civil Engineers, Portugal:

Transactions. September, October, November and December, 1878; January and February, 1879.

From Wm. S. Barbour, City Engineer, Cambridge, Mass.:

Annual Report of City Engineer for 1878.

Fourteenth Annual Report of the Cambridge, Mass., Water Board, 1878.

The Mayors Address and Annual Reports made to the City Council of Cambridge, Mass.

From Walter A. Barlow, London:

Patentees' Journal of Dates. Vol II, No. 7, 1879. W. A. Barlow, Proprietor.

From H. Bartels, Berlin:

Betriebs-Einrichtungen auf Amerikanischen Eisenbahnen I. Bahnhofsanlagen und Signale. H. Bartels, Berlin, 1879.

From Mellen Chamberlain, Boston:

Bulletin of the Boston Public Library, April, 1878. Mellen Chamberlain, Librarian.

From Frederick Brooks, Boston:

Report of the Standing Committee of the Boston Society of Civil Engineers on the Metric System of Weights and Measures, presented March 19th, 1879. (5 copies.)

From Hon. Allan Campbell, Commissioner Department Public Works, New York:

Report of the Department of Public Works, quarter ending December 31, 1878.

From Civil Engineers' Club of the Northwest, L. P. Morehouse, Secretary, Chicago:

The Glasgow Bridge Superstructure. Chas. Sooy Smith.

Blasting under water in Rivers with rapid currents. F. W. Farquhar.

From Eliot C. Clarke, Boston:

Common Defects in House Drains. Eliot C. Clarke. Boston, 1879.

From H. Wadsworth Clarke, Syracuse, N. Y.:

Annual Report of the Superintendent of the Onondaga Salt Springs. A. C. Powell. Albany, 1879.

Journal of the Board of Supervisors of the County of Onondaga for 1878.

Report on the Management and Affairs of the Insane Asylum of the Onondaga County Poorhouse. (2 copies.)

From J. James R Croes, New York:

Annual Report of the State Geologist of New Jersey for 1876.

Report of Water Commissioners of the City of Elizabeth, N. J., for 1868.

From George W. Dresser, N. Y.:

The Electric Light. A paper read before the Society of Gas Lighting, December 12, 1878. Eugene Vanderpool. (2 copies.)

From Charles D. Elliot, Somerville Mass.:

Annual Report of the Board of Harbor Commissioners for 1878.

From Charles E. Billin, Secretary Engineers' Club of Philadelphia:

Proceedings of the Club. Vol. I, No. 2.

From Sanford Fleming, Ottowa, Can.:

Report made to the Minister of Public Works of Canada in reference to the Canadian Pacific Railway. Ottowa, 1879.

From Franklin Institute, Philadelphia:

Journal of the Institute. April and May, 1879.

From George H. Frost, Editor *Engineering News*, New York:

Humber's Water Supply of Cities and Towns. Part 8.

Proceedings Engineer's Club of the Northwest:

1. Pier Constructions of Recent Date. G. A. M. Liljencrantz.
2. Anchor Ice as affecting public Water Supply. John A. Cole.

From Fred. de Funiak, Louisville, Ky.:

Cost of Road Repairs on Louisville and Nashville and South and North Alabama Railroads, for nine months ending March 31st, 1879.

From James T. Gardner, Albany:

Report of New York State Survey for 1878.

From Institution of Civil Engineers, James Forrest, Secretary, London:

Minutes of Proceedings. Vol. LV.

Publications edited by James Forrest, Secretary, as follows:

(1.) The Geelong Water Supply. Edward Dobson.

(2.) The Sandhurst Water Supply. Joseph Brady.

Discussions on the Geelong and Sandhurst Water Supplies.

Railway Bridge over the River Tyne, at Wylam, Northumberland. William G Laws.

On the Best methods of Railway Construction for the development of New Countries. Robert C. Patterson.

Railway Work in Japan. W. P. Potter.

Method of Blasting Rock for the Lyttleton Harbor Works, Canterbury, New Zealand. George Thornton.

From the Institution of Mechanical Engineers, Walter R. Browne, Secretary. London:

Proceedings. January, 1879.

From the Imperial Technic Society, St. Petersburg, Russia:

Notes of the Imperial Technic Society. Part XII. 1878. (Russian.)

From the Iron and Steel Institute. London:

Journal of the Institute, No. 2. 1878.

From John Kennedy, Montreal, Canada:

Annual Report of the Harbor Commissioners of Montreal for 1878.

From Geo. A. Kimball, City Engineer, Somerville, Mass.:

Annual Reports. City of Somerville, Mass., 1878.

First Annual Report of the Board of Health of Somerville, Mass.

Fifth Annual Report of the City Engineer of Somerville, Mass., 1878.

From J. F. Klein, D. E., Philadelphia:

Concerning $\frac{T_1 - T_0}{T_1}$ or the Limit of efficiency of Heat Engines. J. F. Klein, Philadelphia, 1879.

From State Board of Health of Massachusetts, Charles F. Folsom, M. D., Secretary:

Tenth Annual Report of the State Board of Health. January, 1879.

From E. E. Middleton, London:

Impeachment of Modern Astronomy. E. E. Middleton. London, 1879.

From George S. Morison, New York:

Annual Report of the Eastern Railroad Company, 1877-78. Boston, 1878.

From Edward P. North, New York:

Report of the President and Directors of the Northern Pacific Railroad. September 25th, 1878.

From the North of England Institute of Mining and Mechanical Engineers. Theo. Wood Bunning, Secretary. Newcastle-on-Tyne, England:

Transactions of the Institute, February and March, 1879.

From Charles Paine, Cleveland, Ohio:

Ninth Annual Report of the Lake Shore and Michigan Southern Railroad for 1878.

From Wm. H. Paine, Brooklyn, N. Y.:

Specifications for the Steel and Iron Work of the Suspended Superstructure of the East River Bridge.

From Francis Rinecker, Wuerzburg, Germany:

Der Logarithmische Rechenschieber und Seine practische Anwendung. F. Rinecker. Würzburg, 1879.

Die Hydrometrische Waage in ihrem Principe, Wesen und Gebrauch. Franz J. V. Czerwenka. Vienna 1878.

From the Publishers Revue Général des Chemins de fer. Edgar Monjean, Secretary, Paris:

Revue Général des Chemins de fer. January and February, 1879.

From Saxonian Society Engineers and Architects, Leipzic:

Transactions of the Society. Part II. 1878.

From Hon. Horatio Seymour, Jr., State Engineer and Surveyor, Albany;

Annual Report of the New York State Canals for 1878.

From John C. Trautwine, Philadelphia:

Aide Memoire portatif a l'usage des officiers du Génie. Vols. I and II. J. Laisné. Paris, 1861.

A treatise on Internal Navigation. Report of Albert Galatin on Roads and Canals. Ballston Spa, N. Y., 1817.

Bree's Railway Practice. London, 1847.

Bree's Railway Practice. Plates. Vols. I, II, and III.

Bridging the Hudson. Testimony taken before the Senate Committee in the matter of bridging the Hudson River at Albany, February 29th, 1856.

The Miscellaneous papers of John Smeaton, C. E., F. R. S. London, 1814.

Reports of the late John Smeaton. C. E., F. R. S. Vols. I, II and III. London, 1812.

Report of the Department of Mines of Nova Scotia for 1878.

Reports of the Pennsylvania Central Railroad. Two volumes. Volume I, 1848-1855. Volume II, 1856 1860.

Traité Elémentaire des Chemins de fer. Vols. I and II. Aug. Perdonnet. Paris, 1860.

From Edgar B. Van Winkle, New York:

Conditions of Proposals for constructing Sewers and their Appurtenances in Third avenue from Southern Boulevard to 135th street; and in 135th street and 134th street, from Third avenue to Summits east of Willis avenue, with branches in Lincoln, Alexander and Willis avenues.

Conditions of Proposals for Constructing Sewers and Appurtenances in 140th street, from Alexander avenue to Brook avenue, with branches in Alexander and Willis avenues.

Proposals for regulating and grading Third avenue in 23d Ward, and for additional work in said avenue between 147th street and Harlem River.

From D. Van Nostrand, New York:

Van Nostrand's Engineering Magazine. May and June, 1879.

From F. Leypoldt, New York:

The Library Journal. No. 3. Vol. IV.

From Prof. Wm. Watson, Boston:

Reports upon the Public Works of Italy by the Minister of Public Works. 4 folio volumes with full plates.

ANNOUNCEMENTS.

The Eleventh Annual Convention of the Society will be held at Cleveland, beginning Tuesday, June 17th, 1879.

Sessions for the consideration of professional subjects, and one for the transaction of business will be held.

The details of the programme will be announced as soon as determined by the local committee.

The following is a list of topics to be considered with reference to papers published in Transactions during the preceding year:

American Engineering at International Exhibitions.

CLXXIV. American Engineering as illustrated at the Paris Exposition of 1878. George S. Morison, Edward P. North and John Bogart.

BRIDGES.

——— Discussion of Paper CXL. The Determination of Stresses in the Eye-Bar Head. De Volson Wood. Vol. VII, page 189.

——— Discussion of Papers CXLIV and CXLIX. Relative Quantities of Material in Bridges of different kinds, of various heights. William H. Searles. Vol. VII, page 192.

CEMENTS.

——— Discussion on Cements. Don J. Whittemore. Vol. VII, page 274.

——— Discussion on Cements and Strength of Bricks. F. Collingwood. Vol. VII, page 280.

FOUNDATIONS.

CLXXII. The use of Compressed Air in Tubular Foundations, and its application at South Street Bridge, Philadelphia, Pa. D. McN. Stauffer.

HYDRAULICS.

CLX. On the Cause of the Maximum Velocity of Water flowing in Open Channels being below the Surface. James B. Francis.

CLXI. The Flow of Water in Pipes under Pressure. Charles G. Darrach.

—— Discussion on the Cause of the Maximum Velocity of Water flowing in Open Channels being below the Surface, and also on the Flow of Water in Pipes under Pressure. Theo. G. Ellis, C. E. Emery, Clemens Herschel, De Volson Wood and John T. Fanning. Vol. VII., page 122.

CLXVII. Distribution of Rain-fall during the great storm of October 3d and 4th, 1869. James B. Francis.

CLXVIII. The Gauging of Streams. Clemens Herschel.

CLXXV. The Flow of Water in Small Channels, after Ganguillet and Kutter, with Kutter's Diagram modified, and Graphical Tables with special reference to Sewer Calculations. R. Hering.

MASONRY.

CLXX. Brick Arches for Large Sewers. R. Hering.

—— Discussion on Brick Arches for Large Sewers. E. S. Chesbrough, W. Milnor Roberts, R. Hering and F. Collingwood. Vol. VII., page 258.

CLXXI. Fall of Western Arched Approach to South Street Bridge, Philadelphia, Pa D. McN. Stauffer.

—— Discussion on Nomenclature of Building Stones and Stone Masonry. J. Foster Flagg, J. J. R. Croes, J. P. Davis, F. Collingwood, J. Veazie and E. P. North. Vol. VII., page 284.

METALS.

CLXIII. On a newly discovered relation between the Tenacity of Metals and their resistance to Torsion. Robert H. Thurston.

CLXIV. Observations on the Stresses developed in Metallic Bars by Applied Forces. Theodore Cooper.

PRESERVATION OF TIMBER.

CLXXVI. The Permanent Way of Railways in Great Britain and Ireland, with special reference to the use of Timber, preserved and unpreserved. Compiled from information received from Engineers in charge of those railways. John Bogart.

RAILROADS.

CLIX. On the Theoretical Resistance of Railroad Curves. S. Whinery.

—— Discussion on the Resistance of Railroad Curves. O. Chanute, Chas. E. Emery, E. Yardley, E. P. North, C. L. McAlpine, F. Collingwood and Wm. H. Paine. Vol. VII, page 97.

CLXVI. Reminiscences and Experiences of Early Engineering Operations on Railroads, with especial reference to Steep Inclines. W. Milnor Roberts.

—— Discussions on Inclined Planes for Railroads. O. Chanute and William H. Paine. Vol. VII., page 216.

RIVERS AND HARBORS.

CLXII. The South Pass Jetties. Descriptive and Incidental Notes and Memoranda. E. L. Corthell.

—— Discussions on the South Pass Jetties. Charles W. Howell, E. L. Corthell, C. Shaler Smith, J. Foster Flagg. Vol. VII, page 159.

CLXIX. The Dangers threatening the Navigation of the Mississippi River and the Reclamation of its Alluvial Lands. B. M. Harrod.

STEAM ENGINES.

CLXV. Cushioning the Reciprocating Parts of Steam Engines. John W. Hill.

—— Discussion on Steam Engine Economy, J. Foster Flagg and E. D. Leavitt, Jr. Vol. VII, page 194.

SUBMARINE TELEPHONY.

CLXXIII. Submarine Telephoning. Chas. Ward Raymond.

In addition to the above papers, it is expected that the following subjects will be pre-

sented by papers printed previous to the date of the Convention, or read at its meeting:

Engineering Questions involved in the Development of Electric Lighting. Stephen Chester.

Gelatine Dynamite and High Explosives. Julius H. Striedinger.

Lighthouse Construction. J. G. Barnard.

Memoir upon the Construction of the Minots Ledge Light. B. S. Alexander.

The Construction and Maintenance of Roads. Edward P. North.

The Resistances of Railway Rolling Stock. A. M. Wellington.

The Railroad Crossing of the Allegheny Mountain. Moncure Robinson.

Notes on Early Railroad Engineering. Ashbel Welch.

Remarks on the Causes of Fall of the Western Arched Approach to South Street Bridge, Philadelphia, Pa. J. G. Barnard.

Parabolic Arches in Masonry. W. A. G. Emonts.

Notes on the Foundations of Piers of the East River Bridge. F. Collingwood.

Experiments with Cements and appliances for testing. Alfred Noble.

Comparison of Standard Measures, English, French and United States. Arthur S. C. Wurtele.

The South Pass Jetties; the consolidation and durability of the works, with description of the Concrete Blocks and other constructions of the past year. Max E. Schmidt.

Notes as to construction and operation of the Railroad over the Raton Mountains, Col., and the construction and performance of the Locomotives thereon. James D. Burr.

Design and Construction Tables for Egg-shaped Sewers. Cyrus G. Force, Jr.

Traction Experiments to Determine the Resistance of Vessels in narrow Channels or Canals. E. Sweet, Jr.

Wind Pressure. F. Collingwood.

Flexure and Transverse Resistance of Beams. C. E. Emery.

Stability of Stone Piers. Wm. H. Searles.

Cadastral Maps in Ohio. H. F. Walling.

Telford Pavements. James Owen.

A number of members have already signified their intention of taking part in discussions of the papers.

Members of the Society are earnestly requested to furnish information or memoranda upon any of the subjects referred to. They are also invited and expected to take part in the discussions either in person or by sending to the Secretary notes for presentation.

In either case, it wil assist the Committee in arranging the details for sessions of the Convention, if Members expecting to take part in the discussions will notify the Secretary at once to that effect.

Excursions upon the Lake and by rail from Cleveland are contemplated, and the arrangements for them are in progress.

The Secretary is instructed to state that it is permissible that Members of the Society should be accompanied by their families.

Invitation to visit Pittsburg and the Government Works for the improvement of the river at that place (Davis Island Dam), has been extended by James H. Harlow, Member of the Society.

Please notify the Secretary whether you will visit Pittsburg, and whether you will present a paper or take part in the discussions at Cleveland.

Under the rule adopted by the Society in reference to invitations to Conventions, the members of the Boston Society of Civil Engineers, of the Engineers' Club of the Northwest, of the Engineers' Club of St. Louis, of the Engineers' Club of Philadelphia, and of the American Institute of Mining Engineers; also, the Editors of Professional Journals exchanging with this Society have been invited to attend the Convention and the excursions connected therewith.

The following resolution was adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications:

Whereas, the metric system of weights and measures is now extensively used abroad, and whereas it is desirable that the relation of the units of differing systems be made familiar to all by comparison:

Resolved, That members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimensions by the metric system, in connection with those of the system in general use.

The House of the Society is at 104 East Twentieth street, one door from Fourth avenue, and near the southwest corner of Gramercy Park. It is open from nine o'clock A.M. to five o'clock P.M. each business day, except Saturday, when it is closed at three o'clock P. M.

The Library and Conversation Rooms will also, for the present, be open every *Thursday evening*, from 7½ to 10 P. M. Members are invited to avail themselves of the opportunities afforded on Thursday evenings both for consultation of books and periodicals, and for conversation.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

Date of Election.

RICHARDSON, HENRY B...Assistant State Engineer, St. Joseph, La. .....May 7th, 1879.

SCHMIDT, MAX O. E.....Chief Assistant Engineer, South Pass Jetties, Port Eads, La..... " "

ASSOCIATE.

ROBERTS, PERCIVAL, JR....265 South Fourth street, Philadelphia, Pa..... ....May 7th, 1879.

CHANGES AND CORRECTIONS.

MEMBERS.

CISNEROS, FRANCIS J.....311 West Thirty-third street, New York.

SITES, WILMON W. C.....Architect and Civil Engineer, 8 Oakland avenue, Jersey City, N. J.

SPIELMAN, ARTHUR .....13 Newark street, Hoboken, N. J.

JUNIOR.

TASKER, CHARLES A.....Care of John H. Dailey, Cincinnati Southern Railway Office, 80 West Third street, Cincinnati, Ohio.

FELLOW.

COURTWRIGHT, MILTON....19 Courtlandt street, New York.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. V.—June, 1879.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

JUNE 4TH, 1879.—The Society met at 8 P.M. Thomas C. Clarke in the chair.

Ballots for admission to membership were canvassed, and the following were declared elected as members:

Charles Albert Allen of Worcester, Mass.; John Carlisle Bland (elected Junior, May 5th, 1875,) of Philadelphia, Pa.; Edward Bates Dorsey of San Francisco, Cal.; Sullivan Haslett of Brooklyn, N.Y.; and Charles Herne McKee of Albany, N.Y. Also as Fellow, Frederick Oakford Norton of New York.

A communication was presented from N. H. Whitten, Member of the Society, accompanying a communication from the Holyoke Water Power Company, and from the Mayor of the City of Holyoke, inviting this Society to designate an Engineer to attend a trial of Turbines at Holyoke, Mass.*

* The City Government of Holyoke realizing the importance of the following proposition, join with the Water Power Company in inviting the Locks and Canals Company of Lowell, Mass., to send Mr. Francis as Engineer, the City of Philadelphia, Pa., to send an Engineer familiar with the pumping of water for that city, the National Millers' Association to send an Engineer familiar with milling matters, the American Society of Civil Engineers to send an Engineer as representative of that Society, and the representatives of the owners of the turbines furnished for trial to select an Engineer to care for the interests of turbine builders, the five to be guests of the city during the trial, to have full charge of the tests and at the close to report the results in accordance with the proposition of the Water Power Company to the Mayor of this city in order that the said report may be officially promulgated.

J. E. DELANEY, *City Clerk.*

Approved.

WM. WHITING, *Mayor.*

On Motion, the following resolution was adopted: Resolved, that this Society accepts the invitation of the Holyoke Manufacturing Company and the city authorities of Holyoke, Mass., to send a representative to attend the proposed tests of turbines, and that the Board of Direction be requested to designate a member of the Society for that purpose.

A description of a proposed connected girder was presented by Charles E. Emery, and the subject discussed.

JUNE 18TH, 1879.—Regular meeting of the Society, held during the Convention at Cleveland.

The Society met at 8½ P. M. Director Theodore G. Ellis in the chair.

The Committee on Uniform Accounts and Returns of Railroad Companies presented a report* which was read by the Secretary, and on motion the report was accepted and the committee discharged.

The Committee on Tests of American Iron, Steel and other Metals presented a report† which was read by its Chairman, W. Sooy Smith.

On motion the report was accepted and adopted.

HOLYOKE, MASS., May 17, 1879.

To the Secretary of the American Society of Civil Engineers,
New York City:

DEAR SIR:

In behalf of the citizens of Holyoke I hereby cordially invite the co-operation of your Association in accordance with the above.

WM. WHITING, *Mayor.*

HOLYOKE WATER POWER COMPANY.

NOTICE TO TURBINE BUILDERS AND MANUFACTURERS.

The practice of testing turbines, so common the past ten years, has undoubtedly done much towards bringing the best into use; but there has been one serious defect in the system; that is, the practice has generally been confined to the trial of small wheels, owing to the great expense that would be caused by the tests of large sizes. As it is a matter of vast importance that the best turbine plans should be established beyond chance for doubt, this company contemplate providing means for a thorough competitive test of the various kinds of turbines that may be offered for trial, and to invite Water Power Companies, Cities that pump their water supply, and all others interested in the matter, to take part in it. The requirements will be, that the wheels shall be ready for test when delivered at the Holyoke Testing Flume, and that each builder shall superintend the setting of his wheel; the setting and testing to be done at the expense of the Water Power Company. Capacity of each wheel to be sufficient to discharge about 5 000 cubic feet of water per minute, under 18 feet head. Each wheel will be thoroughly tested from half to whole gate, and if deemed best, under at least two different heads; also under several feet of back water. At the conclusion of the trial, a full report will be made of the results obtained and of the workmanship, and probable durability of each kind of wheel tried. Turbine builders of this or any other country are invited to furnish wheels, and those proposing to do so, should give notice of such intention as soon as possible.

Test to commence first day of September next.

WM. A. CHASE, *Agent.*

HOLYOKE, MASS., April 10, 1879.

* See page 33. † See page 36.

W. Sooy Smith moved that the Committee be discharged and that a that a new committee of seven be appointed for the same duty, which motion was lost.

The committee was continued as now composed.

The Committee on Finance then made a report through the chairman, William H. Paine, which on motion was accepted.

The Committee on the Exhibit of the Society at the Paris Exposition made a report of progress through E. P. North, which was on motion accepted.

The following resolution was presented (by letter) by Ernest W. Bowditch, and was, under By-law 23, referred to the Board of Direction for issue of letter ballot :

Resolved, that a standing committee of seven, representing different sections of the country, be appointed from the American Society of Civil Engineers, who shall examine into the entire subject of the preservation of timber and report to the Society from time to time, and who shall collect such samples and data as they may be able, to aid in determining the relative values of the different woods, both preserved and unpreserved, in ordinary use in various parts of the country.

The following resolution was offered by Charles Latimer, and was, with a recommendation for its adoption, under By-law 23, referred to the Board of Direction for issue of letter ballot :

Resolved, that a committee of seven members of the Society be appointed by the Board of Direction to devise and report a uniform system for tests of cement.

The suggestions referred to the Convention at the meeting of May 7th, 1879, (see Proceedings, Vol. V., page 21,) were then taken up and read.

The following additional suggestion was presented, by letter, from William P. Shinn :—That the papers and reports of committees on professional subjects should be allowed to be printed by any or all of the technical journals that think proper to publish them.

The following resolution was offered by O. Chanute :

Resolved, that it is the sense of this meeting that the Board of Direction should take immediate steps to provide for the holding in various cities of three general meetings in each year in addition to the general Convention, for purposes of professional intercourse.

The resolution was discussed by Messrs. Flagg, Bogart, Searles, Cooper, Latimer, Macdonald, Metcalf, Elliot and Chanute.

It was moved by O. Chanute to strike out the word "three" and instead thereof to insert "one or more."

The amendment was lost.

The original motion was lost.

The following resolution was offered by O. Chanute :—Resolved, that the Board of Direction be requested to issue advance copies of papers to

such members or other persons as may be specially qualified to take part in the discussion of the same. That members should be encouraged to make use of the facilities of the Society in New York for obtaining professional information, so far as the same may be secured without entailing onerous labor or expense upon the Secretary.

The resolution was discussed by Messrs. Rotch, Chanute, Flagg and Smedley.

The resolution was adopted.

The following resolution was offered by O. Chanute :—That a Research Committee of five be appointed by the Board of Direction, if authorized by letter ballot, whose duties shall be to collect and publish annually the results of existing experiments upon any subject; to suggest what further experiments are necessary, and also to collate such professional papers as may have been published elsewhere.

This resolution was adopted.

On motion the following, being the second suggestion of May 7th, was adopted as a resolution :—That papers be annually invited from members or other persons upon subjects of general engineering interest, to be specified by the Board of Direction.

On motion the following resolution, based upon the third suggestion of May 7th, was adopted :—Resolved, that the Board of Direction be requested to submit, in the usual manner, a system to award special recognition for the best papers contributed each year.

On motion the following, being the seventh suggestion of May 7th, was adopted :

That the Library Committee be requested to report whether some plan may not be adopted to enable members living away from New York to consult the books of the Library, under proper regulations to ensure their return and to prevent injury.

The following resolution was offered :—That the papers and reports of committees on professional subjects shall be allowed to be printed in any or all journals that think proper to publish them.

This resolution was discussed by Messrs. Dresser, Flagg, Cotton, Emery, Latimer and C. Shaler Smith.

The resolution was adopted.

On motion of F. Collingwood, the Committee on Tests of American Iron, Steel and other Metals were thanked for the work it has done.

The Society then adjourned.

OF THE BOARD OF DIRECTION.

May 31st, 1879.—Applications for membership were considered. Arrangements for the approaching Convention were perfected; appropriations were made, and general business transacted.

JUNE 30TH, 1879.—Applications for membership were considered. In accordance with the resolution adopted by the Society (see page 00), requesting the Board of Direction to designate a member of the Society to attend the proposed test of turbines at Holyoke, Mass., the Board designated William E. Worthen as such member, and in case of his declination or inability to serve, the Board designated Charles E. Emery as an alternate. The Library Committee made a report in reference to the conditions of award of the Norman Medal, which was accepted and forwarded to George H. Norman for his consideration. Appropriations were made.

REPORTS OF COMMITTEES.

PRESENTED AT THE TENTH ANNUAL CONVENTION.

REPORT OF THE COMMITTEE ON UNIFORM ACCOUNTS AND RETURNS OF RAILROAD COMPANIES.

To the American Society of Civil Engineers:

Your Committee on "Uniform Accounts and Returns of Railroad Companies" beg leave to report that, in addition to the influence which the members of your Committee have been able to exert in the furtherance of the object of their appointment, the matter of uniform accounts and returns has been very strongly advocated by Mr. C. F. Adams, Jr., Railway Commissioner of Massachusetts, and that, in consequence of our united efforts, a meeting of the Railway Commissioners of several States was called to be held at Columbus, Ohio, on November 12th, 1878, at which meeting it was the intention of the Chairman of your Committee to have been present, but by some mistake he was advised that the meeting would be held on the 14th, which mistake was not corrected until the day of the meeting. At that meeting a committee was appointed, with instructions to solicit the co-operation of six parties named as experts in railroad accounts, one of whom was the chairman of your Committee.

This General Committee of Commissioners and Experts was called together and held a meeting at the St. Nicholas Hotel, New York, on April 24th, 1879, where the following subjects were discussed:

1st. The general principles upon which accounts should be required to be kept by railroad companies.

2d. The form of returns to be required to be made by railroad companies to the State authorities.

The Chairman of your Committee attended this meeting and took active part in its discussions, as the result of which certain general rules were adopted to govern the keeping of accounts, and a form of returns was agreed upon, with the exception of the heads under which expense should be classified, which was left for further consideration by the Committee, at a meeting to be held June 10th. The rules and forms of returns, so far as adopted by the Committee, are appended hereto.

The Chairman of your Committee was invited to attend the meeting on June 10th, but regrets to say that by reason of ill health he was unable to do so. He is advised, however, by the Secretary of the meeting, that the rules as agreed upon by the Committee at the meeting of April 24th were adopted, and a form for division of expense accounts was agreed upon and adopted, which form is also appended hereto. It only remains, therefore, for the Commissioners of the several States to procure such legislation as will enable them to adopt the agreed forms, when uniform accounts and returns will have been accomplished so far as the States are concerned which have railroad returns.

Opposition may be expected from some

ailroad companies to the requirements of the rules adopted by the Commissioners, but experience in Massachusetts indicates that such opposition will gradually yield, and the railroad companies will find it to be an advantage in the end.

Respectfully submitted.

WM. P. SHINN,
O. CHANUTE,
FRED. DE FUNIAK, } *Committee.*

APPENDIX.

RULES, ETC.

A meeting of the Committee of Railroad Commissioners and Railroad Accountants on "Uniform System of Accounts and Returns," appointed at the General Convention of Railroad Commissioners in November last, was held at the St. Nicholas Hotel, New York City, Thursday, April 24, 1879, as per call of the Chairman, Mr. Woodruff of Connecticut.

There were present of the Committee: Messrs. Woodruff of Connecticut, Carter of Virginia, Turner of Wisconsin, Railroad Commissioners; Messrs. Leland of Ohio, Shinn of Pennsylvania, Wilbur of Boston, Railroad Accountants; and J. H. Goodspeed, Secretary; also, by invitation, Gen. F. A. Walker, Railroad Commissioner of Connecticut, and Mr. George E. Towne, Accountant, of Boston.

On a general discussion of the matter before the Committee, it was unanimously voted,—

"That it is the sentiment of the Committee that the system of accounts and returns should include a showing in detail of the annual operation."

The following general rules, in regard to the manner of keeping accounts from which the returns are to be made, were discussed and adopted:

I.

All liabilities (including interest accrued on funded debt) shall be entered upon the books in the month when they are incurred without reference to date of payment.

II.

Expenses shall be charged each month with such supplies, materials, &c., as have been *used* during that month, without reference to the time when they were purchased or paid for.

III.

No expenditure shall be charged to property accounts, except it be for actual increase in construction, equipments or other property, unless it is made on old work in such a way as to clearly increase the value of the property over and above the cost of renewing the original structures, &c.

In such cases, only the amount of increased cost shall be charged, and the amount allowed on account of the old work shall be stated.

IV.

Mileage of passenger and freight trains shall include only the miles shown to be run by distances between stations; allowances made to passenger or freight trains for switching, and all mileage of switching engines computed on a basis of ten miles per hour for the time of actual service, shall be stated separately.

V.

Season ticket passengers shall be computed on the basis of twelve (12) passengers per week for the time of each ticket.

VI.

Local traffic should include all passengers carried on local tickets, and all freight carried at local tariff or special local rates.

All other traffic shall be considered through.

The form of return upon which the reports are to be made to the Commissioners was taken up and decided upon, with the exception of the division of operating expenses.

A form of division of operating expenses was submitted by Mr. Towne, and the Secretary was instructed to send copies of the same, together with the rules and form adopted, to the different members of the Committee, asking them to take it under consideration for discussion and final decision at the next meeting of the Committee, to be held at the time of the General Convention of Railroad Commissioners in June next.

The form of return as adopted by the Committee is as follows:

GENERAL EXHIBIT.

Total income.....
Total expense.....
Net income.....
Interest on funded debt.....
" " unfunded debt.....
Rentals.....
Balance applicable to dividends.....
Dividends declared (per cent.).....
Balance for the year.....

Balance (profit and loss) last year.....
(Add or deduct various entries made during the year not included above (specifying same.)
Balance (profit and loss) carried forward to next year.....

CHARGES AND CREDITS TO PROPERTY DURING THE YEAR.

Construction and equipment (specifying same).....
Other charges (specifying same).....
Total charges.....
Property sold or reduced in value (specifying same).....
Net addition (or reduction) for the year ..

ANALYSIS OF EARNINGS AND EXPENSES.

Earnings :
From local passengers.....
Through .....
Express and extra baggage..... ....
Mails.....
Other sources, passenger department ..
Total earnings passenger department.....
Local freight.....
Through freight.....
Other sources, freight department.....
Total earnings, freight department.....
Total transportation earnings.....
Rents from use of road.....
Income from other sources (specifying same).....

Total income from all sources....

EXPENSES.

(See form submitted.)

ASSETS AND LIABILITIES.

Assets :
Construction account .....
Equipment " .....
(Locomotives, No.).....
(Parlor and sleeping cars, No.).....
(Passenger cars, No.).....
(Baggage and mail cars, No.).....
(Freight cars, No.).....
(Other cars, No.).....
Other investments (specifying same).....

Cash items :
Cash .....
Bills receivable.....
Due from agents and companies .....

Other assets :
Materials and supplies .....
Sinking funds.....
Debit balances.....

Total assets..... .....

Liabilities :
Capital stock (as specified below).....
Funded debt (as detailed below).....
Unfunded debt, as follows :
Interest unpaid..... .....
Dividends unpaid.....
Notes payable .....
Vouchers and accounts .....
Other liabilities.....
Profit and loss or income accounts.....

Total liabilities.....

PRESENT OR CONTINGENT LIABILITIES NOT INCLUDED IN BALANCE SHEET.

Bonds guaranteed by this company or a lien on its road (specifying same).....
Overdue interest on same.....
Other liabilities (specifying same).....

MILEAGE, TRAFFIC, ETC.

Mileage passenger trains.....
Freight " ....
Switching " .....
Other " .....

Total train mileage.....

Miles run by passenger, mail, and baggage cars (north or east).....
Miles run by passenger, mail, and baggage cars (south or west).....
Miles run by freight cars (north or east)..
" " " " (south or west)..
Number of season ticket passengers.....
Number of local passengers (including season).....
Number of through passengers.....
Total number of passengers carried.....
Mileage of local passengers (north or east)
" " " (south or west)
Mileage of through passengers (north or east).....
Mileage of through passengers (south or west).....

Total passenger mileage.....

Number tons local freight carried.....
" " through " " .....

Total tons freight carried ....

Mileage of local tonnage (north or east)...
" " " (south or west) ..

Mileage of through tonnage (north or east)
" " " (south or west)

Total freight mileage .....

Average weight of passenger trains.....
" number of cars in passenger trains .....
Average weight of freight trains .. ..
" number of cars in train.....
" " persons employed....
Length of road, branches, sidings, &c....
Names of officers and directors .....
Corporate name of company.....

OPERATING EXPENSES.

Salaries general officers and clerks .....
Law expenses .....
Insurance.....
Stationery and printing.....
Outside agencies and advertising.....
Contingencies .....
Repairs bridges (including culverts and cattle guards.....
Repairs buildings.....
" fences, road crossings, and signs
Renewal rails.....
Renewal ties .....
Repairs roadway and track.....
" locomotives .....
Fuel " .....
Water supply.....
Oil and waste.....
Locomotive service.....
Repairs passenger cars.....
Passenger train service .....
" " supplies.....
Mileage passenger cars.....
Repairs freight cars.....
Freight train service.....
" " supplies .....
Mileage freight cars... ....
Telegraph expenses (maintenance and operating) .....
Damage and loss freight and baggage.....
" " property and cattle .....
Personal injuries .....
Agents and station service.....
Station supplies .....

Total operating expenses ....
Taxes.....

Total operating expenses and taxes.....

Report of Committee on Tests of American Iron and Steel.

To the American Society of Civil Engineers:

Your Committee on Tests of American Iron and Steel begs leave to submit the following report: At the Annual Convention of the Society, held at the City of Chicago seven years ago, your Committee on Tests was created. By frequent reports, and by papers read before the Society, you have been kept fully advised of the efforts made by the committee to procure from Congress the necessary appropriations for carrying on the work of the United States Testing Board. You have also been informed of the scheme of investigations devised by the Board, and the progress made in such investigations. Two appropriations have been obtained, amounting in the aggregate to ninety-four thousand three hundred and ninety-six dollars and ninety-eight cents—the odd dollars and cents accruing by the addition of an unexpended balance to a round sum. The act making the last appropriation provides that when the money has been expended the Board shall cease to exist, and that the testing machine built under the direction of the Board, and for its use, shall be turned over to the Secretary of War. As you are aware, the machine was but recently completed. By directions given the Board at the time of its organization, this machine has been erected at the Watertown Arsenal, situated at Watertown, Massachusetts. As soon as it is turned over to the Secretary of War it drops into the possession of the United States Ordnance Department, subject to this further provision of the act referred to, that parties desiring to have tests made can do so by paying for the same The money will all be expended before the end of the present fiscal year, which closes June 30th, inst. At the end of this month, then, the machine will be turned over and the United States Testing Board will cease to exist. For seven years your committee has importuned Congress for the necessary appropriations, with such measure of success as has been reported to you. For four years the Board has labored under many difficulties to plan and carry forward the work confided to it. A plan of investigation, which has received the hearty approval of this Society and of eminent engineers throughout the world, has been arranged. Such investigations as

could be economically and effectively carried on without the use of the long delayed machine, have been faithfully prosecuted by some of the sub-committees of the Board, and as a foretaste of the valuable results anicipated by us all from the labors of the United States Testing Board reports have recently been made by these committees, which will at once become standard authority on the subjects treated. Our Society, the Testing Board, and the country at large, have compensation for the long delay in the completion of the testing machine, in its unprecedented excellence, now that it is done. The labors of the Board, but just begun, have yielded benefits worth many times the gross amounts of the money appropriated, and our Government has for future use by far the best testing machine in the world.

From time to time, during the last seven years, your committee has performed the distasteful duties which devolve upon the "third house" at Washington, not corruptly, but honestly and earnestly commending a most worthy object to the attention and support of he Government. In the performance of this work its members have willingly spent large sums of money in necessary expenses and much valuable time, glad of the opportunity to make this contribution to so important a branch of scientific inquiry. Many members of the Society, and some of the manufacturers of iron and steel, besides numerous scientific societies and institutions of learning, have aided the committee with their valuable influence. To all these your committee desire to return sincere thanks. And we desire to ask that you will overlo k or forgive the shortcomings which have occurred in our efforts to perform the duties assigned to us.

Engineers throughout our country realize the urgent need of the knowledge which the tests proposed were designed to procure. The country at large realizes it and fully approves the appropriation of the public money for this beneficent purpose.

Appropriatons have been obtained; the necessary machinery has been provided; the Board seemed well selected; the work was auspiciously begun, when a bolt shot from a sky that was already lowering when we held our convention in New Orleans, two years ago, struck the United States Testing Board, the pet child of our Society, *dead.*

If you cannot weep over its fall, picture to yourselves the tragedies which result from the ignorance which it was created to remove, and think of the symmetry, strength and perfection of the structures which American engineers would have given to the world, aided by the knowledge which this effort was designed to procure.

Who, we ask the "American Society of Civil Engineers," are the rightful owners of the testing machine and other appliances procured with the people's money for the use of the United States Testing Board? If the people, then let it be retained in the service of the people to promote the common interests of the country and not be turned over to any single bureau or department of the Government specially skilled only in a particular line of inquiry.

The knowledge we so much desire and so sorely need, can only be obtained by a mixed Board of experts independent of the control of any particular governmental department, except so far as the honest expenditure of the money appropriated is concerned.

Now, what will our Society, with its membership of six hundred, distributed in every State and Territory of the United States, do in this matter? Have we the necessary power and influence to induce the Government to right the grievous wrong that it has done us? Or are we a mutual admiration society which meets periodically to air fine spun theories, in utter unconsciousness of the density of the ignorance that envelops us? If these questions are couched in language lacking grace or courtesy, the Society is asked to pardon the want, and to remember that the threatened failure of an effort earnestly prosecuted for seven years, is likely to provoke strong language

Your committee respectfully recommends that a new committee be appointed, the Chairman of which should reside at or near Washington, and that a ten times more vigorous effort than any yet made by the Society be put forth to recover what has been lost by inattention. As engineers, and as a society, we owe it to the Committee and Board who have labored so long without pay, to procure the means and to make the tests. We owe it to our country and to the world, since the work had been so auspiciously begun, to see to it that it shall not be permitted to fail until the knowledge we so much need, and which is now just within our grasp, has been secured and thoroughly digested and prepared for common use.

WM. SOOY SMITH,
Chairman of Committee on Tests.

Report of the Finance Committee.

Presented verbally by William H. Paine, Chairman.

I did not expect to make a report this evening, but being acquainted with the finances of the Society, I will make a statement as I think it due to you that a report should be made.

I will state that the Finance Committee on their organization took up all the papers of every character representing the expenses of last year, and audited them most carefully and fully, and found them correct; further, that with the assistance of the Secretary and Treasurer, the Finance Account is now in such a shape that the auditing for the present year is very simple. I will further state that the Committee has made it a point to meet regularly and audit the bills and to keep them in such a manner that they can be fully understood at all times; this could only be done by the full co-operation of the Secretary and Treasurer.

I will state that the bills which were outstanding, of which mention has been made at previous meetings, the number and amounts of which were unknown, have been obtained through the course of procedure of asking every person who receipted a bill to sign the bill in full. We think that all bills are now in, so that the Society is out of debt, which condition I think we have reason to congratulate this Society upon. Furthermore, the state of our Finances has been such that the publications of the Society were far in the background; at one time, nearly or quite ten months; at the commencement of this year, I think, about five months; so that we have been obliged to work very carefully, and to husband expenses and proceed with caution, requiring a great deal of energy and watchfulness on the part of those who were entrusted with this matter; and I now congratulate the Society upon the fact that just before the Secretary started for this meeting, he mailed the last copies for the last month, so that we are up to date with our publications, which is, I think, a fact worthy of congratulation. It is a matter, too, which interests those more particularly who are not residents of New York, who are not present at the meetings of the Society. Those who are near can understand what is going on. The Finance Committee have felt, as well as the officers, that it was of the utmost importance that the member farthest distant should get the fullest information of the proceedings as promptly as possible, so as to make this Society national in its character, instead of a Society simply belonging to the City of New York.

I might go on with other matters, but think I have said enough. It has only been by the most industrious labor on the part of the Secretary and the Library Committee, whom you will perceive have had double and more work to do, that we have been enabled to reach this result. I hope you will receive this verbal report, and I will not occupy your time longer.

ANNOUNCEMENTS.

At the Meeting of the Society to be held August 6th, a paper by Max E. Schmidt, member of the Society, will be presented, subject, "The South Pass Jetties, Notes on the construction and durability of the works, with a description of the concrete blocks and other constructions of the last year." This paper will be put in print and will be discussed at the meeting of the Society to be held October 15th, 1879. Advance copies of the paper will be sent to persons who will contribute discussion.

At the meeting of September 3d, a paper by William H. Searles, member of the Society, subject, "The Stability of Stone Structures," will be read and discussed. Advance copies of this paper will be sent to persons who desire to discuss the subject.

At the meeting of September 17th, a paper by James D. Burr, member of the Society,

subject, "The Construction of the A. T. and S. F. R. R., over the Raton Mountains," will be read and discussed. Advance copies of this paper will be sent to persons who desire to discuss the subject.

At the meeting of October 1st, the paper No. CLXXX (Transactions May 1879), on the Construction and Maintenance of Roads, by Edward P. North, member of the Society, and the discussions presented on the same at the Convention at Cleveland will be considered and further discussed. Advance copies of these discussions will be furnished to persons desiring to discuss the subject.

Discussion on each of these subjects is especially invited. The Secretary will forward the advance copies to those who inform him of their desire to discuss. The discussions may be presented verbally or sent to the Secretary, who will read them for the authors.

The following resolution was adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications:

Whereas, the metric system of weights and measures is now extensively used abroad, and whereas it is desirable that the relation of the units of differing systems be made familiar to all by comparison:

Resolved, That members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimensions by the metric system, in connection with those of the system in general use.

The House of the Society is at 104 East Twentieth street, one door from Fourth avenue, and near the southwest corner of Gramercy Park. It is open from nine o'clock A.M. to five o'clock P.M. each business day, except Saturday, when it is closed at three o'clock P. M.

The Library and Conversation Rooms will also, for the present, be open every *Thursday evening*, from 7½ to 10 P. M. Members are invited to avail themselves of the opportunities, afforded on Thursday evenings both for consultation of books and periodicals, and for conversation.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

		Date of Election.
ALLEN, CHARLES A.	City Engineer, Worcester, Mass.	June 4th, 1879.
BURDEN, JAMES A.	Burden Iron Works, Troy, N. Y.	July 2d, "
DORSEY, EDWARD B.	261 Fifth Avenue, New York	June 4th, "
HASLETT, SULLIVAN	115 Clinton st., Brooklyn, N. Y.	" " "
MEIGS, MONTGOMERY	U. S. Civil Eng., Rock Island, Ill.	March 5th, "
THOMPSON, WM. G. M.	Engineer in charge Welland Canal Enlargement, Welland Canal, Ontario, Canada	July 2d, "

FELLOW.

NORTON, FREDERICK O.	90 Broadway, New York	June 4th, "

CHANGES AND CORRECTIONS.

MEMBERS.

ENDICOTT, M. T.....U. S. Navy Yard, Portsmouth, N. H.

KENNEDY, WILLIAM H.....Principal Asst. Engineer, Oregon Pacific Railroad, Walla Walla, Washington Territory.

KINSLEY, THOMAS P.....508 Franklin ave., Brooklyn, N. Y.

LOW, GORHAM P., Jr.....Asst. Engineer Missouri River Bridge, Plattsmouth, Nebraska.

MILLER, REUBEN.....Crescent Steel Works, 81 Wood st., Pittsburgh, Pa.

OPDYKE, STACY B., Jr.....Engineer New Haven and Northampton, Co., 271 Chapel st., New Haven, Conn.

SMEDLEY, SAMUEL L.....Chief Engineer and Surveyor of Philadelphia, East Entrance City Hall, Philadelphia, Pa.

THATCHER, EDWIN.....Keystone Bridge Co., Pittsburgh, Pa.

JUNIOR.

TASKER, CHARLES A.....Asst. Engineer, New York and Wood Haven Railroad, Wood Haven, Long Island, N. Y.

DECEASED.

BELL, JAMES E..... Elected Member March 5th, 1879. Died June 8th, 1879.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. V, July, 1879.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

ELEVENTH ANNUAL CONVENTION OF THE SOCIETY.

First Session.—The Eleventh Annual Convention was held at Cleveland, Ohio, beginning Tuesday June 17th, 1879. The Society met in the Council Chamber of the City which had been kindly offered for the purpose. The Secretary, John Bogart, called the Convention to order at 10 A. M. The chair was taken by Director and Past Vice-President, Theodore G. Ellis. The Hon. R. R. Herrick, Mayor of the City, then addressed the Convention as follows:

Gentlemen,—This is, as I am informed, the Eleventh Annual Convention of the American Association of Civil Engineers. I understand that there are representatives here from several countries of the American continent.

You have assembled from these different sections for one of the grandest purposes for which it is possible for men to meet together, and so intent upon the single object on which your thoughts are bent, you forget the difference of nationality, the difference of location and all the other differences which might tend to estrange one from the other and join hands, hearts and minds in the work of advancing that science and art whose function it is to utilize the forces and material of nature and cause them to subserve the general good.

You are to be congratulated upon choosing this city at this season of the year as the place of holding your convention. We possess broad streets and avenues, the beauties of some of which have a world-wide reputation. The charming effect of the combination of art with nature is here observed. The abundance of trees,

some of which are relics of the "forest primeval," and whose refreshing shade is now most grateful, has given us the name of the "Forest City." We have also our parks wherein are seen on a somewhat limited scale the product of one branch of engineering art, the efforts of your brethren in the craft to imitate nature. Upon our northern boundary we have an inland sea from off whose bosom fresh breezes almost continually blow "To fan our people cool" and on whose water sail many ships which bring to us much of our prosperity.

To our City, gentlemen, with all her attractions and her generous hospitality, of which I believe you will receive ample proof before your departure, you are most welcome.

Cleveland delights to receive within her boundaries such men as you. She is pleased to do honor to the students and practical demonstrators of that science which is doing more to develop the material resources of our country than all else besides. Your profession and the aims and objects of your gathering insures for you a most cordial greeting. We are fully aware of the relation which your profession sustains to the general development of our country. We know the vast scope which it comprehends and realize the debt of gratitude we owe to your predecessors and yourselves for our present advanced state of prosperity. We appreciate the great progress of the past sixty years, and know that the profession of engineering was the chief instrumentality in its accomplishment. Within that time it has covered our oceans, lakes and rivers with independent steamships, which ask no favors of the uncertain winds, but plow the waters, "pursuing the even tenor of their way" regardless of the quarter from which it blows. It has ditched the surface of the land for thousands of miles, thereby making canals for the safe and convenient transportation of merchandise. It has netted our country with railroads, arteries through which the life-blood of the nation continually flows. It has spanned our rivers and valleys with majestic viaducts and bridges. It has delved to the center of the earth and brought out the minerals which constitute the chief source of our wealth. It has tunnelled mountains and elevated valleys that the highway of trade might be made easy. It has constructed breakwaters and embankments, aqueducts, light-houses, docks, dams and sewers. All improvements small and great, incident to the growth of cities, States and nations are the products of its labors. As we traverse with ease and safety the viaduct that spans the valley, which lies between two sections of our own city, we appreciate the triumph of the engineering art and the skill and ability of our own townsmen, Strong, Morse and Miller, who have proven themselves "Masters of the situation." We gladly welcome their brethren in convention here assembled, and trust their sojourn with us may be both pleasant and profitable. It affords me pleasure in the name and behalf of the citizens of Cleveland to tender to you the freedom of the city.

The Chairman, Gen. T. G. Ellis, responded as follows:

Mr. Mayor—In the name of the American Society of Civil Engineers, allow me to return to you our sincere thanks for this cordial reception. The courtesies extended to us by the members of the Society residing in Cleveland, and by others of your citizens, as shown in the progamme arranged by the local committee, are, let me assure you, highly appreciated. We shall return to our homes with our

hearts filled with pleasure by the kindness of our welcome, and our minds stored with knowledge by what we have seen.

Again let me thank you for our cordial welcome to your beautiful city.

Charles Paine, of Cleveland, was then chosen as Permanent Chairman of the Convention, and, on taking the chair, referred to the fact that while there were sixty civil engineers in Cleveland, that number represented only a fraction of the engineering talent concentrated there, it being in fact a city of mechanical engineers. All these members of our profession welcomed the Convention to the city with great enthusiasm, and had been so kind in the tender of invitations to visit the many points of engineering interest that the Committee had been much embarrassed in arranging the details for the few days at its disposal.

After referring to the geological position of the city and the programme prepared for excursions, he called the Convention to order to proceed to business.

John Bogart was then chosen to act as Secretary of the Convention. and George W. Dresser as Deputy Secretary.

The roll was then called, and the following members and guests were found in attendance.*

Members of the Society.—E. R. Andrews, Boston ; James Archbald, Scranton, Pa.; Theodore Allen, St. Louis ; Geo. D. Ansley, Montreal ; W. H. Bradley, F. Brooks, Boston; John W. Bacon, Danbury, Conn.; H. D. Blunden, John Bogart, New York; C. B. Brush, Hoboken, N. J.; C. E. Broadhead, Hickory Run, Pa.; E. N. Beebout, Canton, Ohio ; G. Bouscaren, Cincinnati ; W. R. Relknap, Louisville ; D. W. Cunningham, Grantville, Mass.; J. P. Cotton, Newport, R. I.; O. Chanute, F. Collingwood, Theodore Cooper, New York ; W. B. Coffin, Elmira, N. Y.; M. Coryell, Lambertville, N. J. ; E. S. Chesbrough, Chicago ; C. Constable, Rockwood, Tenn.; George W. Dresser, New York ; Charles Davis, Alleghany City, Pa.; C. Wheeler Durham, Chicago ; Fred. de Funiak, Louisville, Ky.; S. C. Ellis, Boston; C. D. Elliott, Somerville, Mass. ; Theo. G. Ellis, Hartford, Conn.; Thomas Egleston, C. E. Emery, New York ; H. Earnshaw, Cincinnati ; John E. Earley, Florence, Ala.; E. A. Flint, Boston ; C. E. Fowler, New Haven, Conn.; Clark Fisher, Trenton, N. J.; Charles H. Fisher, Albany, N. Y.; J. F. Flagg, Meadville, Pa.; C. G. Force, Jr., Cleveland, Ohio ; H. Fladd, St. Louis ; B. Godwin, New York ; F. Graff, Philadelphia, A. Gottlieb, Pittsburgh, Pa. ; J. M. Goodwin, Sharpsville, Pa. ; Alex. Gordon, Hamilton, O.; A. B. Hill, New Haven, Conn.; R. Hering, Philalelphia ; J. E. Hilgard, Washington, D. C. ; J. W. Hill, Cincinnati ; J. H. Harlow, Pittsburgh, Pa. ; T. S. Hardee, B. M. Harrod, New Orleans, La. ; W. E. Kelley, New Brunswick, N. J. ; M. W. Kingsley, Cleveland ; John Kennedy, Montreal ; T. C. Keefer, Ottawa, Canada ; D. J. Lucas, Corry, Pa. ; Charles Latimer, Cleveland, O. ; T. D. Lovett, Winton Place, O.; W.

* This list includes those who arrived at the Convention later.

H. Lotz, Chicago; Charles Macdonald, Geo. S. Morison, Chas. H. Myers, New York; D. N. Melvin, New Springville, Staten Island, N. Y.; J. R. Maxwell, Newark, Del.; D. E. McComb, Washington, D. C.; N. M. McDowell, Alleghany City, Pa.; Wm. Metcalf, Pittsburgh, Pa.; C. S. Maurice, Athens, Pa.; B. F. Morse, Cleveland, O.; W. E. Merrill, Cincinnati; W. F. Merrill, Peoria, Ill.; John MacLeod, Louisville, Ky.; E. P. North, F. O. Norton, New York; W. J. Nicolls, Baltimore; R. M. Newman, Jackson, Mich.; Alfred Noble, Detroit, Mich.; G. B. Nicholson, Cincinnati; W. H. Paine, New York; Charles Paine, Cleveland, O.; P. A. Peterson, Montreal; Wm. Rotch, Fall River, Mass.; Thomas Rodd, Pittsburgh, Pa.; R. L. Read, Cincinnati; H. B. Richardson, New Orleans; W. H. Searles, New York; E. Sweet, Jr., Albany, N. Y.; S. L. Smedley, Philadelphia; F. Slataper, Pittsburgh, Pa.; T. R. Scowden, S. Sheldon, C. H. Strong, Cleveland, O.; H. E. Stevens, St. Paul, Minn.; C. Shaler Smith, St. Louis; W. Sooy Smith, Maywood, Ill.; E. N. K. Talcott, Morgan Park, Ill.; E. B. Van Winkle, New York; F. O. Whitney, Boston; J. Whitney, Cambridge, Mass.; W. H. Wiley, W. E. Worthen, New York; J. Whitelaw, Cleveland, O.; H. F. Walling, Marietta, O.; F. C. Weir, Cincinnati; D. J. Whittemore, Milwaukee, Wis.; T. J. Whitman, St. Louis; S. Whinery, Wheeler, Ala.

Visiting Engineers.—E. C. Appleton, Geo. H. Crafts, T. W. Davis, H. L. Eaton, F. L. Fuller, F. A. May, William Watson, Boston; E. S. Davis, Lowell, Mass.;* H. Constable, L. M. Haupt, L. C. Madeira, Philadelphia;† Geo. H. Frost, New York; A. Wolcott, Chicago;‡ N. P. Bowler, C. F. Brush, Cleveland, O.; H. R. Bradbury, London, England; H. M. Claflen, J. D. Crehore, Cleveland, O.; D. Le Roy Dresser, New York; Jörgen Dahl, Christiana, Norway; G. Geuder, Cleveland, O.; C. E. Greene, Ann Arbor, Mich.; F. Hind, Watertown, N. Y.; J. F. Hollaway, Cleveland, O.; Wm. Kent, Pittsburgh, Pa.; J. N. Knapp, Cleveland, O.; Thos. B. Lee, Newark, N. J.; M. D. Leggett, Cleveland, O.; F. A. Mahan, Pittsburgh, Pa.; A. G. Mordecai, Cleveland, O.; A. Meriwether, M. Meriwether, Memphis, Tenn.; M. W. Niven, Hoboken, N. J.; A. H. Porter, M. E. Rawson, W. P. Rice, Cleveland, O.; E. A. Rudiger, St. Marys, O.; E. H. Talbott, Chicago; J. Wainwright, A. M. Wellington, M. C. Younglove, Cleveland, O.

On motion, the following Committee was appointed to determine the order of presentation of papers and of discussions: O. Chanute, of New York, W. E. Merrill, of Cincinatti, John Kennedy, of Montreal.

A communication was presented from the Union Club of Cleveland, tendering a reception on the evening of June 19th. On motion, this invitation was accepted.

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* Members Boston Society Civil Engineers.

† Members Engineers Club of Philadelphia.

‡ Members Engineers Club of the Northwest.

A paper by E. Sweet, Jr., subject: "The Engineering problems involved in the proposed improvement of the Erie Canal, by increasing the depth of its channel one foot;" was read by the author, and discussed by C. H. Fisher, Theodore Allen, William Watson, G. Bouscaren and the author.

A paper by Alfred Noble, subject: "Experiments with appliances for testing cement," was read by the author, and the subject was discussed by D. J. Whittemore, F. Collingwood, W. Sooy Smith, D. W. Cunningham, J. H. Harlow, C. Latimer, F. O. Norton, A. Noble, and, by letter, F. Rinecker.

Second Session.—The Convention resumed its session at 8 p. m.

Professor C. F. Brush made an address upon the electric light, which was illustrated by the stereopticon.

A paper, by C. G. Force, Jr., subject: "Design and Construction Table for Egg-shaped sewers," was read by the author, and illustrated by the Stereopticon.

A graphic chart, systematically showing the accounts of a railway, was presented, illustrated by the Stereopticon and explained by Charles Latimer.

A paper, by Charles Macdonald, subject: "The Construction of the Ocean Pier at Coney Island," was presented, illustrated by the Stereopticon, and read by the author. It was discussed by C. Shaler Smith, J. Whitelaw, G. W. Dresser, C. B. Brush, and the author.

The specifications for the Glasgow Steel Bridge were then read by the author, W. Sooy Smith, and discussed by W. H. Paine, G. Bouscaren, A. Gottlieb, Wm. Kent, C. Macdonald, W. Metcalf, C. G. Force, F. Collingwood, and the author.

Third Session.—The Convention resumed its session at 10 a. m., Wednesday, June 18th.

The Committee to determine the order of presentation of papers and of discussions, submitted the following resolutions, which were adopted:

Resolved, that in order to expedite business, each speaker be limited to ten minutes, unless by consent of the Convention.

Resolved, that discussions on published papers shall take precedence of new papers, so far as practicable.

A paper by Charles E. Emery, subject: "Flexure and Transverse Resistance of Beams," was read by the author, and discussed by William Kent.

A paper, by F. Collingwood, describing the progress of the work on the New York and Brooklyn Bridge, was read by the author.

A discussion of the published papers on the subject of the relative quantities of material in Bridges of different kinds of various heights, was presented by Charles E. Emery.

The published papers on the subject of the theoretical resistance of railroad curves, were discussed by J. F. Flagg, S. Whinery, and W. H. Searles.

The published paper by Edward P. North, subject: "The Construction and Maintenance of Roads," was discussed by Charles B. Brush, C. Shaler Smith, G. Bouscaren, E. B. Van Winkle, and by letters, F. Lavoinne, of Auxerre, France; F. Rinecker, of Wurzburg, Germany; and Charles Douglas Fox, of London, England.

Fourth Session.—The regular meeting of the Society was held Wednesday evening, June 18th (see page 30 *ante*). At the close of the regular meeting the Convention resumed its session and proceeded to the business prescribed by Section 24 of the By-Laws: "At the Annual Convention a Nominating Committee of five members, not officers of the Society, shall be appointed by the Convention."

Nominations were made, and a ballot being taken, the following members were appointed by the Convention as the Nominating Committee:

Thomas S. Hardee, of New Orleans, La.; Thomas C. Keefer, of Ottawa, Canada; Charles Paine, of Cleveland, Ohio; Thomas J. Whitman of St. Louis, Mo.; Joseph P. Davis, of Boston, Mass.

On motion of W. E. Merrill, the following resolution was adopted:

Resolved, that the President of the Society be requested to establish such relations with the authorities at Washington, who print public documuents as will enable the members of this Society to procure engineering documents on the best terms.

Fifth Session.—The Convention resumed its session at 10 A. M., Thursday, June 19th.

The discussion of the published paper on the construction and maintenance of roads was resumed and continued by D. E. McComb, E. R. Andrews, C. Shaler Smith, G. Bouscaren, G. D. Ansley, E. S. Chesbrough, A. B. Hill, J. E. Hilgard, H. Flad, M. Merriwether, B. F. Morse and the author, E. P. North.

The published paper by John Bogart, subject, "The permanent way of railways in Great Britain and Ireland, with special reference to the use of timber preserved and unpreserved," was discussed in a paper read by E. R. Andrews, and the subject further discussed by C. Latmer, E. Sweet, Jr., Wm. Watson, T. Egleston, C. Paine, J. Kennedy and, by letter, E. W. Bowditch.

On motion, it was

Resolved, that the Convention recommend the appointment of a Standing Committee on the Preservation of Timber. (See Proceedings, page 31 *ante*.)

A discussion of the published papers on the subject, "Brick Arches for Large Sewers," was presented in a letter from C. Herschel, and the subject further discussed by R. Hering.

The published paper by James B. Francis, subject, "The distribution of rain fall during the great storm of October, 1869," was discussed by W. Rotch.

The subject of a comparison of Standard Measures, English, French and United States was presented by abstracts from a paper by A. S. C. Wurtele and discussed by J. E. Hilgard, T. G. Ellis and C. Latimer.

The published paper by John W. Hill, subject, "Cushioning the reciprocating parts of Steam Engines," was discussed by C. E. Emery and the author, J. W. Hill.

The published paper by D. McN. Stauffer, subject, "The use of compressed air in Tubular foundations and its application at South Street Bridge, Philadelphia," was discussed by F. Collingwood.

The published papers by R. Hering, subject, "The Flow of Water in Small Channels, after Ganguillet and Kutter," was discussed in a paper, sent with a letter, by C. H. Swan, and further discussed by R. Hering.

A paper by John Kennedy, subject, "The Improvement of the St. Lawrence River," was read by the author.

The following unpublished papers were presented during the Convention, but not read on account of the want of time after the conclusion of the discussions on published papers :

Brazil, its Railways and Water Communications, W. Milnor Roberts.

The South Pass Jetties—the consolidation and durability of the works, with description of the Concrete Blocks and other constructions of the past year. Max E. Schmidt.

Discussion on the South Pass Jetties. H. D. Whitcomb.

Notes as to Construction and Operation of the Railroad over the Raton Mountains, Col., and the Construction and Performance of the Locomotives thereon. James D. Burr.

The Flow of Water in Rivers. De Volson Wood.

Stability of Stone Structures. Wm. H. Searles.

Wind Pressure. F. Collingwood.

Cadastral Maps in Ohio. H. F. Walling.

Additional notes on the Submarine Telephone. Chas. W. Raymond.

The following resolutions were adopted :

Resolved, that the Convention desires to express its hearty appreciation of and thanks for the great kindness, attention and forethought of the Local Committee in making preparations and carrying out the many details of arrangements for this Convention.

Resolved, that the warmest thanks of this Convention be tendered to the Mayor and other authorities of the City of Cleveland, to its citizens and to the city press, as well as to the various manufacturing and other establishments which we have visited, for their kind attentions and hospitality, which have made this Convention one of the plesantest and most successful which the Society has ever held.

Resolved, that the thanks of the Convention be extended to Mr. Charles Paine for the able and courteous manner in which he has presided over its deliberations.

Resolved, that the thanks of the Convention be extended to the Managers of Railways and other lines of Transportation who have extended facilities for enabling the members to visit the Convention and return to their homes.

Resolved, that the thanks of the Convention are extended to the Committee which has so well discharged its duties in preparing and presenting the report regarding the Paris Exposition and our exhibits there.

Adjourned.

Very complete arrangements were made by the Local Committee for the time occupied in the regular sessions above reported. The visits to the many points of engineering interest in Cleveland and its immediate vicinity were so managed as to give to the members of the Society and their guests quite as full information in regard to the many industrial and mechanical works of the city as the time allowed. The excursions after the close of the Convention were also of great interest, and were fully enjoyed.

The members of the Cleveland Local Committee were: Charles Paine, Chairman; S. Sheldon, Charles H. Strong, T. R. Scowden, John Whitelaw, E. T. Scovill, Charles Latimer, B. F. Morse, J. Newell, M. W. Kingsley; C. G. Force, Jr., Sec'y and Treas.

The general programme for each day was printed in pocket form, with a monogram of the Society on the cover. It was distributed to members and guests, and was as follows:

AMERICAN SOCIETY OF CIVIL ENGINEERS.

ELEVENTH ANNUAL CONVENTION.

The headquarters of the Society will be at the Forest City House, Monumental Park. The Meetings of the Society will be held in the City Council Chamber, City Hall, on Superior Street, East of the Park, three minutes' walk from the Society headquarters. Take the elevator in the main entrance, City Hall. By the courtesy of the City Council the Council Chamber is placed at the disposal of the Society.

The Local Committee on Convention request each member and invited guest to call at the rooms of the Committee at headquarters immediately on arrival.

The members are requested, as soon as possible after their arrival, to signify to the Secretary which of the Excursions he proposes to join, and whether accompanied by ladies.

Ladies accompanying Members and Guests are invited to join all the Excursions, except on Wednesday afternoon.

TUESDAY, JUNE 17.

Convention will be called to order at 10 A. M. Hon. R. R. Herrick, Mayor of Cleveland, will welcome the Society in behalf of the citizens of Cleveland. Session. Adjournment. Dinner.

In the afternoon, leaving the hotel at 2 o'clock, an excursion in charge of Mr. B. F. Morse, City Civil Engineer, will be made to the Cleveland Viaduct; thence to the Reservoir and Pumping Works of the Cleveland Water Works; at this point the party will be in charge of Mr. John Whitelaw, Chief Engineer of the Water Works Department. Returning, will visit the Telegraph Supply Company's Works, Nos. 145 and 147 St. Clair street. Here the party will be in charge of Hon. M. D. Leggett, President of the Company, assisted by Professor Charles T. Brush, the inventor of the Brush Electric Lamp and the Brush Dynamo-Electric Machine. Prof. Brush will have a machine taken apart and one in operation, and will explain the working of his apparatus.

The excursion will end with a drive to the Union Steel Screw Company's Works, by the way of Euclid avenue. Here the party will be in charge of Mr. J. A. Bidwell, Superintendent of the Works. Returning, will visit the private grounds of J. H. Wade, Esq., owner of Euclid and Case avenues, thence by the way of Prospect street to the hotel.

At 7:45 p. m., the regular Society Meeting, to which the public is invited. The acting President of the Society will deliver an address, giving a summary of Engineering progress during the preceding years.

WEDNESDAY, JUNE 18.

Mr. Charles H. Strong, Manager of the Day.

The Convention will be called to order at 10 A. M. Session. Adjournment—Dinner.

In the afternoon there will be an excursion to some of the manufacturing establishments of the city, by way of the Cleveland & Pittsburg and Atlantic & Great Western Railroads. Special train will leave the Union Passenger Depot at 2 P. M., arriving at the Otis Iron and Steel Company's Works at 2:05. Here the party will be in charge of Hon. Charles A. Otis, President of the Otis Iron and Steel Company. Leaving at 2:25, will arrive at the St. Clair Street Crossing 2:28; from here Mr. H. M. Claflin, President of the Cleveland Bridge and Car Works, will escort the party to the works of that company; thence in charge of Mr. Zenas King, President of the King Iron Bridge and Manufacturing Company, to the works of this company, making a short stop at the Novelty Iron Works, Thomas R. Reeves, President. Leave St. Clair Street Crossing at 3; arrive at the Cleveland Rolling Mill Co.'s Works at 3:20. Here the party will be in charge of Mr. Henry Chisholm, President of the company, assisted by Mr. Willson Chisholm, Superintendent of the Newburgh Works. Thence by way of the A. & G. W. R. R., special train, leaving at 4:35, will arrive at the works of the Standard Oil Co. at 4:50. Here the party will be met by Mr. A. M. McGregor, Superintendent of the

Manufacturing Department of the Standard Oil Co., assisted by Mr. W. P. Cowen, Superintendent of the company's works at Cleveland.

Leaving the Standard Oil Co.'s Works at 6:00; will arrive at the Union Passenger Depot at 6:30, and at the hotel at 6:50.

By the courtesy of the officers of the C. & P. and the A. & G. W. R. R's, special trains will be run for the accommodation of the excursion party.

The locomotive whistle will be sounded five minutes before leaving each stopping point.

During the stay at the various points the movements of the party will be directed by the Manager of the Day, giving his signal with a policeman's whistle.

By invitation of Miss Sarah E. Fitch, President of the Women's Christian Association, an opportunity will be given the ladies to visit some of the benevolent institutions of the city. Carriages will be in waiting at the hotel at 2:30 P. M.

Session and business meeting at 7:45 P. M.

THURSDAY, JUNE 19.

There will be a social meeting of the Society at 10 A M., at the City Council Chamber.

Two excursions have been provided for this afternoon.

Excursion on the lake. *John Whitelaw, manager.*

By the courtesy of Captain L. A. Pierce, agent of the Michigan Central R. R. Line of Steamers, there will be an excursion on the steamer *City of Detroit,* Captain William McKay. Invitations have been extended to members of the profession and others to join this excursion accompanied by ladies.

Members joining this excursion will leave the hotel at 1:45 P. M. in carriages, arriving at wharf No. 23 East River street 1:55. The boat leaves at 2 P. M., returning at 5 P. M. On the way out the steamer will sail around the Water Works Crib, and if the weather is favorable an opportunity will be given by those who wish to land and examine the work.

Excursion to Berea and Amherst Stone Quarries. *Charles Paine, manager.*

Those who wish to visit these stone quarries will leave the hotel at 2 P. M., and the Union Depot at 2:15 P. M., thence by way of the C. C. C. & I. Railway; will arrive at Berea at 2:45 P. M., change to open cars and go into the Berea Quarries, under the guidance of Mr. Frank Ford, Chief Engineer, C. C. C. & I. Railway. Returning to Berea Station at 3:45 P. M., take excursion coaches and proceed to Amherst Quarries. Returning by way of L. S. & M. S. R. R., will leave Amherst at 6 P. M., and arrive at the Union Depot at 7 P. M.

By the courtesy of the officers of the C. C. C. & I. and the L. S. & M. S. R. R., a special train will be run for the accommodation of the party.

RECEPTION.

The Union Club of Cleveland, S. L. Mather, President, has tendered a reception to the Society and its invited guests, at the Club House, No, 417 Euclid avenue, about five minutes' walk from the headquarters, Thursday evening, June 19, commencing at 8 o'clock. Those wishing to ride can take the Prospect street cars in front of the hotel direct to the entrance on Euclid avenue.

FRIDAY, JUNE 20.

Charles Latimer, Manager of the Day.

On this day an excursion will be made to the Mahoning Valley coal fields. The party will leave the hotel in carriages at 7:40 A. M., and the Atlantic & Great Western depot at 8 A. M.; arrive at Leavittsburgh at 9:20 A. M.; here a car hoist and transfer may be witnessed. Leave Leavittsburgh at 9:40 A. M.; arrive at Vienna Junction at 10:15 A. M., and arrive at Church Hill coal mines at 10:25 A. M. Here the party will be in charge of Mr. John Tod, President of the Coal Company of Tod, Morris & Co. Leave Church Hill at 11:25 A. M.; arrive at Youngstown at 11:45 A. M.; headquarters at the Tod House. The citizens of Youngstown have provided dinners for the party and carriages for drives to points of interest in Youngstown and vicinity during the afternoon.

During the stay in Youngstown Mr. Robert McCurdy and Mr. Chauncy Andrews will direct the movements of the party. Returning, will leave Youngstown at 4:50 P. M. Arrive at Cleveland at 7:15 P. M.

The excursion train will be under the direction of J. M. Ferris, Superintendent of the M. D. of the A. & G. W. R. R.

BRADFORD OIL DISTRICT.

Members not desiring to go into the Mahoning Valley Coal Fields may take the 7:10 A. M. express on the A. & G. W. R. R., arriving at Bradford at 5:15 P. M. Leaving Bradford at 2:20 P. M. on the next day, can connect with the main line going east at 3 P. M. For the west leave Bradford at 10 A. M. and make close connections, or at 4 P. M. and connect with the main line at 11:39 P. M.

NIAGARA FALLS.

Arrangements have been made, by which eastern members and others wishing to visit the Falls, may leave Cleveland on any of the regular trains, connecting at Buffalo for Niagara Falls.

A large party left Cleveland, as arranged by the above programme, for the Mahoning Valley Coal Fields, where a descent was made into the Great Church Hill Mine. Youngstown was then visited, and industrial works of much engineering interest examined. The Society and its guests were hospitably entertained by a committee of the citizens of Youngstown. A number of the party then visited Niagara Falls.

Another party visited the Oil District at Bradford, Pa., where, under the kind guidance of Mr. Charles Newell, the operations of drilling and tubing oil wells, pumping oil, endeavoring to recover tools lost in the wells, etc., were inspected. The use of natural gas for heating and cooking was also observed.

On Monday morning, June 16th (the day previous to the Convention), a large number of the members of the Society and their guests, *en route* for Cleveland, arrived at Pittsburgh, Pa. Here they were met by the members resident in that city, and first visited the works at Davis Island, where a lock and system of movable dams is in course of construction

by the United States Government. The operations in progress and the plans for completion were explained by Lieut. F. A. Mahan, United States Engineers, and James H. Harlow, member of the Society.

The Edgar Thomson Steel Works were also visited, and the details of the works, which were in full progress, were inspected.

The new engines at the pump houses of the City Water Works of Pittsburgh, were also examined.

July 2d, 1879.—The Society met at 8 p. m. William E. Worthen in the chair.

Ballots for admission to membership were canvassed, and the following were declared elected as members: James A. Burden, of Troy, N. Y., and William G. M. Thomson, of Welland, Ontario, Canada.

The death, on Sunday, June 8th, 1879, at Cincinnati, of James E. Bell, member of the Society, was announced, and the President was authorized to appoint a committee to prepare a memoir of the deceased.

The Board of Direction reported the designation of William E. Worthen to attend the tests of turbines, in accordance with the resolution of the Society of June 4th, 1879. In case of inability to serve by Mr. Worthen, the designation of Charles E. Emery, as an alternate, was announced.

A Paper by W. Milnor Roberts, on the subject of Brazil, its Railway and Water Communications, was read by the Secretary, and discussed by members present.

July 16th, 1879.—The Society met at 8 p. m. Thomas C. Clarke in the chair.

A Paper by De Volson Wood, subject, "The Flow of Water in Rivers," was read by the Secretary, and discussed by Messrs. Clarke, Cooper, North, J. F. Ward, and Yardley.

LIST OF NEW BOOKS ON

ENGINEERING AND TECHNOLOGY.

Alphabets, Pocket Book, including Church Text, Egyptian, Egyptian Perspective, French, French Antique, French Renaissance, German Text, Italic, Italian Shaded, Italian Hairline, Monograms, Old English, Old Roman, Open Roman, Open Stone, Ornamental. Roman, Latin, Rustic, Tuscan, &c. New York. *Spons.* $0.20.

Anemometer, On the Determination of the Constants of the Cup Anemometer, by Experiments with a Whirling Machine. From the Philosophical Transactions of the Royal Society. Part 2. 1878. 4to. T. R. Robinson. London. *Trubner.* 5s.

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———, Coal Mines Inspection: Its History and Results. R. Nelson Boyd. London. 8vo. *W. H. Allen.* 14s.

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Railway Accidents. Inspector's reports. *British Govmt. Pub.* 5s. 9d.

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Railway reports, American ——; collection of all reported decisions relative to railways, Vol. 11, 13, 14, 15, 16 (W. W. Ladd, Jr.). N. Y., *Cockroft & Co.* 1878–79. Ea. 8° shp., $6.00.

Railways, Narrow Gauge. C. E. Spooner. London and New York. 8vo, illus., 2d ed. *Spons.* $6.

Record, Annual, of Science and Industry for 1878. Spencer F. Baird. New York. 8vo. *Harpers.* $2.00.

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1879. (Smithsonian miscellaneous collection, 328.) Cloth, 8vo.

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Weights and Measures Act, 1878 (41 and 42 Vict., Chap. 49); including a practical summary of the Act, with Notes and Cases, together with the memorandum prefixed to the Act, &c.; also the Bread Act, 1836, so far as it relates to Weights and Measures. Slade Butler. 12mo. London. *Shaw & Sons.* 4s.

ADDITIONS TO

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From American Chemical Society, P. Cassamajor, Secretary, New York:

Journal of the Society, Vol. I, Nos. 3 and 4.

From American Iron and Steel Association, James M. Swank, Secretary, Philadelphia:

Annual Report of the Secretary for 1878.

Proceedings of the Convention of Iron and Steel Manufacturers and Iron Ore Producers at Pittsburgh, Tuesday, May 6th, 1879.

From Administration des Ponts et Chaussées, Paris:

Annales, April, 1879.

From Edward R. Andrews, Boston:

Chimney Construction. R. M. Bancroft, London.

From Argentine Scientific Society. Don Felix Amoretti, Secretary, Buenos Ayres:

Anales. May, 1879.

From O. Chanute, New York:

General Specifications for Iron Bridges, N.Y., L. E. & W. R. R. Co. O. Chanute, Chief Engineer. (Copies for distribution.)

From J. James R. Croes, New York:

Report on Additional Water Supply for the City of Newark, N. J. By J. J. R. Croes & Geo. W. Howell. March 6th, 1879.

From Joseph P. Davis, City Engineer, Boston:

Fifteenth Annual Report of the Overseers of the Poor of the City of Boston for 1878-9.

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A new Centre of Gravity Formula of general applicability.

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Verhandlungen der General Versammlung des Vereins deutsches' Cement-Fabrikaten. Feb. 3d, 4th and 5th, 1879.

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Proceedings of the Club. Vol. I, No. 3.

From Franklin Institute, Philadelphia:
Journal of the Institute. June and July, 1879.

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Supplementary Report of the Committee on Water Supply of Brookline, Mass., with letter of Gen. George S. Greene.

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Communication from the Secretary of State in response to a resolution of the House of Representatives, in relation to the Convention for establishing an International Bureau of Weights and Measures.
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From Institution of Mechanical Engineers, Walter R. Browne, Secretary, London:
Proceedings of the Institute, April, 1879.

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Articles of Association of the New York and Honduras Company.
The Rosario Mining Company of Honduras, Central America.

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Proceedings of the Road Masters meeting of the Atlantic and Great Western Railway held at Meadville, Pa., Nov. 14, 1878.

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Abstract of registers New York Meteorological Observatory for January, February, March and April, 1879.

From Minister of Public Works, Versailles, France:
Ports Maritimes de la France, Part III.

From Ernest Pontzen, Paris, France:
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Renseignements économiques sur l'emploi des Locomotives a air comprimé pour la traction des Tramways et des Chemins de fer souterrains.

From New York Produce Exchange, James L. Flint, Secretary, New York:
Annual Report of the New York Produce Exchange for 1878.

From the Publishers, Revue Generale des Chemins de fer, Edgar Monjean, Secretary, Paris, France:
Revue Generales des Chemins de fer, March and April, 1869.

From Society of Engineers, Perry F. Nursey, Secretary, London, England:
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Report on the Difference of Longitude between Washington and St. Louis. Wm. Harkness.

Tables of Instrumental Constants and Corrections for the reduction of Transit Observations. J. R. Eastman.
The Uranian and Neptuanian Systems investigated with the 26-inch Equatorial. S. Newcomb.

From Robert Van Buren, Brooklyn, N. Y.;
Annual Report of the Board of City Works of Brooklyn for 1878.

From H. D. Whitcomb. Richmond, Va.:
Annual Report of the James River Improvement Commission for year ending January 31, 1870.

From other sources :
A description of the Billerica and Bedford 2-feet gauge Railroad.
The American Catalogue, Vol. 1, Authors and Titles. Part 3, Lenoir. Robbie.
The Library Journel. Vol. IV, No. 6.
New Mode of Making Foundations and Anchoring Piles in unstable bottoms or quicksands. Charles Pontez, Patentee.
Reports of the Departments of the Government of the City of Cleveland for year ending December 31, 1877.

THE NORMAN MEDAL.

The following rules have been adopted by the Board of Direction, with the approval of the donor of the Medal Fund, George H. Norman, Member and Fellow of the Society :

CODE OF RULES

FOR THE

AWARD OF THE NORMAL MEDAL.

I.—Competition for the Norman Medal of the American Society of Civil Engineers shall be restricted to Members of the Society.

II.—There shall be one gold medal, and only one, struck for each and every fiscal year of the Society, and awarded as hereinafter provided. The dies therefor shall be with the Superintendent of the United States Mint at Philadelphia, in trust exclusively for the above purpose. Such medal shall be of a cost equal to the annual interest received upon $1,000.00 of the Consolidated Stock of the City of New York, Certificate No. 179, of the additional new Croton Aqueduct Stock of the City of New York, authorized by an Act of the Legislature of the State of New York, Chap. 230, passed April 15th, 1870, dated November 17th, 1873, now held in trust by the Treasurer of this Society, and so held solely for this purpose, and shall be executed upon his order.

III.—All original papers presented to the Society by members of any class, during the year for which the medal is awarded, shall be open to the awards, provided that such papers shall not have been previously contributed in whole or in part to any other association, nor have appeared in print prior to their publication by the Society, nor have been presented to the Society in any previous year.

IV.—The Board of Censors to award the Medal shall consist of three members of the Society, to be designated by the Board of Direction. The Secretary of the Society shall act as Secretary to the Board of Censors.

V.—The medal shall be awarded to such paper as the said Board shall judge to be worthy of special commendation for its merits as a contribution to Engineering Science, not merely relatively as compared with others presented during the same year, but as exhibiting the science, talent, or industry displayed in the consideration of the subject treated of, and for the good which may be expected to result from the discussion and the inquiry.

VI.—In case no paper presented during the year shall be deemed of sufficient value to receive an award, the amount of the interest of the fund for that year shall be expended by the Board of Direction in the purchase of books, to be offered as a premium for the second best paper in the next year in which more than one paper of sufficient value may be presented.

VII.—The medal year shall terminate on the first day of August, and the award shall be announced at the Annual Meeting in November.

VIII.—The Treasurer of this Society shall cause the medal to be prepared and delivered to, or deposited to the order of, the successful competitor, within two months after the Annual Meeting at which the same shall have been awarded.

ANNOUNCEMENTS.

At the Meeting of the Society to be held August 6th, a paper by Max E. Schmidt, member of the Society, will be presented, subject, "The South Pass Jetties, Notes on the construction and durability of the works, with a description of the concrete blocks and other constructions of the last year." This paper will be put in print and will be discussed at the meeting of the Society to be held October 15th, 1879. Advance copies of the paper will be sent to persons who will contribute discussion.

At the meeting of September 3d, a paper by William H. Searles, member of the Society, subject, "The Stability of Stone Structures," will be read and discussed.

At the meeting of September 17th, a paper by James D. Burr, member of the Society, subject, "The Construction of the A. T. and S. F. R. R., over the Raton Mountains," will be read and discussed. At the same meeting a paper by Theodore Cooper, Member of the Society, subject, "The use of Steel for Bridges," will be read and discussed. Advance copies of these papers will be sent to persons who desire to discuss the subject.

At the meeting of October 1st, the paper No. CLXXX (Transactions May 1879), on the Construction and Maintenance of Roads, by Edward P. North, member of the Society, and the discussions presented on the same at the Convention at Cleveland will be considered and further discussed. Advance copies of these discussions will be furnished to persons desiring to discuss the subject.

Discussion on each of these subjects is especially invited. The Secretary will forward the advance copies to those who inform him of their desire to discuss. The discussions may be presented verbally or sent to the Secretary, who will read them for the authors.

The following resolution was adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications:

Whereas, the metric system of weights and measures is now extensively used abroad,

and whereas it is desirable that the relation of the units of differing systems be made familiar to all by comparison:

Resolved, That members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimensions by the metric system, in connection with those of the system in general use.

The House of the Society is at 104 East Twentieth street, one door from Fourth avenue, and near the southwest corner of Gramercy Park. It is open from nine o'clock A.M. to five o'clock P.M. each business day, except Saturday, when it is closed at three o'clock P. M.

The Library and Conversation Rooms will also, for the present, be open every *Thursday evening*, from 7½ to 10 P. M. Members are invited to avail themselves of the opportunities, afforded on Thursday evenings both for consultation of books and periodicals, and for conversation.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. V, August, 1879.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

August 6th, 1879.—The Society met at 8 p. m., William E. Worthen in the chair. Ballots for admission to membership were canvassed, and the following were declared elected: As Members, James H. Cunningham, of Milwaukee, Wisconsin; Frederick H. Lehnartz, of Portland, Oregon; and John M. Titlow, of Philadelphia, Pennsylvania; and as Junior, George B. Cornell, of New York.

The death on July 17th, 1879, at Philadelphia, of Franklin A. Stratton, Member of the Society, was announced, and the President was authorized to appoint a committee to prepare a memoir of the deceased.

The paper by Max E. Schmidt, subject: "The South Pass Jetties," which was presented at the Convention at Cleveland, was read by the Secretary and discussed.

THE NORMAN MEDAL.

The following rules have been adopted by the Board of Direction, with the approval of the donor of the Medal Fund, George H. Norman, Member and Fellow of the Society:

CODE OF RULES
FOR THE
AWARD OF THE NORMAN MEDAL.

I.—Competition for the Norman Medal of the American Society of Civil Engineers shall be restricted to Members of the Society.

II.—There shall be one gold medal, and only one, struck for each and every fiscal year of the Society, and awarded as hereinafter provided.

The dies therefor shall be with the Superintendent of the United States Mint at Philadelphia, in trust exclusively for the above purpose. Such medal shall be of a cost equal to the annual interest received upon $1,000.00 of the Consolidated Stock of the City of New York, Certificate No. 179, of the additional new Croton Aqueduct Stock of the City of New York, authorized by an act of the Legislature of the State of New York, Chap. 230, passed April 15th, 1870, dated November 17th, 1873, now held in trust by the Treasurer of this Society, and so held solely for this purpose, and shall be executed upon his order.

III.—All original papers presented to the Society by members of any class, during the year for which the medal is awarded, shall be open to the awards, provided that such papers shall not have been previously contributed in whole or in part to any other association, nor have appeared in print prior to their publication by the Society, nor have been presented to the Society in any previous year.

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VI.—In case no paper presented during the year shall be deemed of sufficient value to receive an award, the amount of the interest of the fund for that year shall be expended by the Board of Direction in the purchase of books, to be offered as a premium for the second best paper in the next year in which more than one paper of sufficient value may be presented.

VII.—The medal year shall terminate on the first day of August, and the award shall be announced at the Annual Meeting in November.

VIII.—The Treasurer of this Society shall cause the medal to be prepared and delivered to, or deposited to the order of, the successful competitor, within two months after the Annual Meeting at which the same shall have been awarded.

LIST OF TOPICS

ON WHICH ORIGINAL PAPERS ARE INVITED.

The Board of Direction submit the following list of topics, on which original papers, illustrating the experience of the writers, are requested:

1.—Topographical Surveys, and the laying out of Towns and the most economical divisions of property.

2.—Instruments and methods of exact measurement for land surveys.

3.—Trigonometrical and Astronomical surveys.

4.—Systems of roadmaking and maintenance suitable for (*a*) large towns and heavy traffic; (*b*) Surburban districts; (*c*) Rural districts.

5.—The sustaining power of different kinds of soils and the conditions which produce failure of foundations by settlement.

6.—The weight which can be supported by different classes of masonry.

7.—The preservation of masonry structures.

8.—The manufacture of cements and methods of testing their strength.

9.—The proportions of cementing and inert materials in mortars.

10.—The preservation of timber used in construction.

11.—The strength, durability and characteristics of various timbers.

12—The manufacture of iron and steel in America. Combinations of materials, methods employed and plant used

13—The properties and laws of cast iron, wrought iron, steel and other metals used in construction.

14.—The effect of constant or long continued vibration on metals used in construction.

15.—The design, generally, of iron bridges of large span.

16.—The construction and operation of drawbridges of large span.

17.—Testing machines and experiments on the strength of materials and structures.

18.—Appliances and methods of rock boring and blasting.

19.—Sub-aqueous tunnels. Their design and construction.

20.—The flow of water in channels of various kinds, and the modes of determining the discharge by experiment. Also the discharge over weirs and through orifices.

21.—The loss of water in flowing in open channels.

22.—The relations of rainfall, character of soil, and flow of streams; effect of wooded and of cleared and cultivated land on the flow of streams.

23.—The sources and systems of water supply for towns, including storage of surface water, open wells, tube wells, gathering galleries, and ground water obtained from different geological strata.

24.—Systems of water supply suitable for small communities, whether separately or co-operatively.

25.—The detection and prevention of waste of water in towns.

26.—The design, construction, and cost of operation of pumping engines, and mode of computing duty.

27.—The history of the manufacture of cast iron water pipes in America.

28.—The strength and dimensions of cast iron pipe and of wrought iron pipe for water supply. Forms of joints for water pipe.

29.—Durability and cost of water pipe of cast iron, wrought iron and cement, wood, and other materials.

30.—The design and construction of earth embankments and masonry dams for reservoirs.

31.—The construction, dimensions, and operation of navigable canals.

32.—Methods of overcoming differences of level in canals.

33.—The improvement and training of rivers.

34.—The construction of harbors of refuge.

35.—The construction of wharves, piers and docks.

36.—The construction of fire-proof buildings.

37.—The warming and ventilation of buildings.

38.—House drainage.

39.—The sewerage of towns and the disposal of sewage.

40.—The form, material and dimensions of sewers.

41.—The economical location of railroad lines.

42.—The construction and maintenance of the permanent way on railroads.

43.—The form, manufacture and life of rails.

44.—The form and material of railway wheels.

45.—The heating and lighting of railroad cars.

46.—The prevention of accidents at railroad crossings and intersections.

47.—Rapid transit in large cities.

48.—The prevention of noise from heavy railroad trains moving at high speed.

49.—Safe substitutes for animal power on surface railways.

50.—The relative economy of the several kinds of fuel used in locomotive engines.

51.—The operation of freight and passenger traffic on railroads, and the conditions of economy in the same.

52.—The arrangement of terminal stations on trunk lines of railroads.

53.—The manufacture, distribution, measurement and use of illuminating gas.

54.—Electricity as applied to lighting and to motive power.

55.—The modern construction of water wheels and engines.

56.—The engineering questions involved in the location and management of large Industrial Exhibitions.

57.—Manufacture, strength and durability of earthenware pipe.

58.—The relations of Engineers to Employers and to contractors.

59.—The Status and Compensation of Experts.

60.—Engineering and Mechanical Law.

ANNOUNCEMENTS.

At the Meeting of the Society to be held September 3d, a paper by William H. Searles, member of the Society, subject, "The Stability of Stone Structures," will be read and discussed. Advanced copies of this paper will be sent to persons who desire to discuss the subject.

At the meeting of September 17th, a paper by James D. Burr, member of the Society, subject, "The Construction of the A. T. and S. F. R. R., over the Raton Mountains," will be read and discussed. At the same meeting a paper by Theodore Cooper, Member of the Society, subject, "The use of Steel for Bridges," will be read and discussed. Advance copies of these papers will be sent to persons who desire to discuss the subject.

At the meeting of October 1st, the paper No. CLXXX (Transactions May 1879), on the Construction and Maintenance of Roads, by Edward P. North, member of the Society, and the discussions presented on the same at the Convention at Cleveland will be considered and further discussed. Advance copies of these discussions will be furnished to persons desiring to discuss the subject.

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Discussion on each of these subjects is especially invited. The Secretary will forward the advance copies to those who inform him of their desire to discuss. The discussions may be presented verbally or sent to the Secretary, who will read them for the authors.

The following resolution was adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications:

Whereas, the metric system of weights and measures is now extensively used abroad, and whereas it is desirable that the relation of the units of differing systems be made familiar to all by comparison:

Resolved, That members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimensions by the metric system, in connection with those of the system in general use.

The House of the Society is at 104 East Twentieth street, one door from Fourth avenue, and near the southwest corner of Gramercy Park. It is open from nine o'clock A.M. to five o'clock P.M. each business day, except Saturday, when it is closed at three o'clock P. M.

The Library and Conversation Rooms will also, for the present, be open every *Thursday evening*, from 7½ to 10 P. M. Members are invited to avail themselves of the opportunities, afforded on Thursday evenings both for consultation of books and periodicals, and for conversation.

LIST OF MEMBERS.

ADDITIONS.

MEMBER.

		Date of Election
BLAND, JOHN C.	(Elected Junior May 5th, 1875), Office of Supervising Architect, Treasury Department, Washington, D. C.	June 4th, 1879.

JUNIOR.

CORNELL, GEORGE B.	Ass't Engineer East Side Line Met. Elev. R. R., 141 Centre St., New York	August 6th, 1879.

CHANGES AND CORRECTIONS.

MEMBERS.

CHITTENDEN, SAMUEL H..U. S. Ass't Engineer, Olio, St. Clair Co., Alabama.

MARSLAND, EDWARD.....New York Gas Light Co., Cor. Twenty-first St. and Avenue A, New York.

NICHOLS, O. F.....202 Academy St., Trenton, N. J.

NICOLLS, WILLIAM J.....Supervisor Long Island Railroad, Jamaica, Long Island, N. Y.

PEARSONS, GALEN W.....Kansas City, Kansas.

JUNIORS.

HAINES, CASPAR W.....Supervisor Sub-Division 1, Pittsburg, Fort Wayne and Chicago Railroad, Eastern Division, Pittsburg, Pa.

HORTON, SANFORD.....Engineer Department. Atchison, Topeka and Santa Fé Railroad, Topeka, Kansas.

DECEASED.

STRATTON, FRANKLIN A..Elected Member May 3d, 1876. Died July 17th, 1879.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. V, September, 1879.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

SEPTEMBER 3D, 1879.—The Society met at 8 P.M. Charles H. Haswell in the chair. Ballots were canvassed, and the following declared elected as Members: Frederick N. Finney of Milwaukee, Wis.; John Thomas Lansing of Albany, N.Y., and Henry G. Prout (elected Associate November 6th, 1872,) of Harrisburg, Pa.

A paper by William H. Searles, subject, "The Stability of Stone Structures," was read by the author. Advance copies of this paper having been issued, discussions were presented through the Secretary from O. Chanute, Theodore Cooper, D. J. Whittemore, F. Collingwood and R. Hering. The subject was also discussed by Charles E. Emery, Charles Macdonald and the author.

SEPTEMBER 17TH, 1879.—The Society met at 8 P. M. Thomas C. Clarke in the chair. The paper by Theodore Cooper on the "Use of Steel for Bridges" was read by the Secretary and discussed by T. C. Clarke, A. P. Boller, C. Macdonald, O. Chanute and D. Torrey. The discussion of the paper by James D. Burr on the "Construction of the Railroad over the Raton Mountains" was postponed till the next meeting.

THE NORMAN MEDAL.

The following rules have been adopted by the Board of Direction, with the approval of the donor of the Medal Fund, George H. Norman, Member and Fellow of the Society:

CODE OF RULES
FOR THE
Award of the Norman Medal.

I.—Competition for the Norman Medal of the American Society of Civil Engineers shall be restricted to Members of the Society.

II.—There shall be one gold medal, and only one, struck for each and every fiscal year of the Society, and awarded as hereinafter provided. The dies therefor shall be with the Superintendent of the United States Mint at Philadelphia, in trust exclusively for the above purpose. Such medal shall be of a cost equal to the annual interest received upon $1,000.00 of the Consolidated Stock of the City of New York, Certificate No. 179, of the additional new Croton Aqueduct Stock of the City of New York, authorized by an act of the Legislature of the State of New York, Chap. 230, passed April 15th, 1870, dated November 17th, 1873, now held in trust by the Treasurer of this Society, and so held solely for this purpose, and shall be executed upon his order.

III.—All original papers presented to the Society by members of any class, during the year for which the medal is awarded, shall be open to the awards, provided that such papers shall not have been previously contributed in whole or in part to any other association, nor have appeared in print prior to their publication by the Society, nor have been presented to the Society in any previous year.

IV.—The Board of Censors to award the Medal shall consist of three members of the Society, to be designated by the Board of Direction. The Secretary of the Society shall act as Secretary to the Board of Censors.

V.—The medal shall be awarded to such paper as the said Board shall judge to be worthy of special commendation for its merits as a contribution to Engineering Science, not merely relatively as compared with others presented during the same year, but as exhibiting the science, talent, or industry displayed in the consideration of the subject treated of, and for the good which may be expected to result from the discussion and the inquiry.

VI.—In case no paper presented during the year shall be deemed of sufficient value to receive an award, the amount of the interest of the fund for that year shall be expended by the Board of Direction in the purchase of books, to be offered as a premium for the second best paper in the next year in which more than one paper of sufficient value may be presented.

VII.—The medal year shall terminate on the first day of August, and the award shall be announced at the Annual Meeting in November.

VIII.—The Treasurer of this Society shall cause the medal to be prepared and delivered to, or deposited to the order of, the successful competitor, within two months after the Annual Meeting at which the same shall have been awarded.

LIST OF NEW BOOKS ON

ENGINEERING AND TECHNOLOGY.

Army. Report of the Russian Army and its Campaigns in Turkey in 1877–8. By Lieutenant F. V. Greene, United States Army. Attaché to the American Legation at St. Petersburg. Accompanied by a military atlas. New York. *Appletons.* (Announcement.)

Art. The Industrial Arts in Spain. By Juan F. Riano. Illustrated with 50 woodcuts. (South Kensington Museum Art Handbooks.) 12mo. New York. *Scribner & Welford.* $1.50.

Bridges. Elementary Theory and Calculation of Iron Bridges and Roofs. By August Ritter, Dr. Phil., Professor at the Polytechnic School at Aix-la-Chapelle. Translated from the German (Third Edition) by H. R. Sankey, Lieut. R. E. *Spons.* London. (Announcement.)

Cables. Strength of Wrought-iron and Chain Cables. Government experiments by Commodore Beardslee. Edited by Wm. Kent. 8vo. New York. *Wiley.* (Announcement.)

Car-builder's Dictionary. by a committee of Master Car-builders' Association. Illustrated. New York. *Railroad Gazette.* $2.25.

Chemistry, Laboratory teaching. C. Bloxam. Philadelphia. 12mo ill. *Lindsay & Blakiston.* $1.75

—— List of new and important books on Chemical Analysis, Assaying, etc. Philadelphia, *Henry Carey Baird & Co.*

Concrete. A Practical Treatise on Natural and Artificial Concrete: Its Varieties and Constructive Adaptations. By Henry Reid, author of "The Science and Art of the Manufacture of Portland Cement," &c. New ed., 8vo. *Spons.* London. 15s.

Dictionary of Engineering: Supplement to Spons. Edited by Ernest Spon. (To be completed in Three Divisions.) Division I. Containing Abacus—Agricultural Implements—Air Compressors—Animal Charcoal Machinery—Barn Machinery—Belts and Belting—Blasting—Boilers—Brake—Brick-making Machines—Bridge—Cages—Calculus—Canals—Carpentry—Cast-iron—Cement, Concrete, Limes and Mortar—Chimney Shafts—Coal Mining, &c., &c. 8vo. *Spons.* London. 13s. 6d.

Electric Transmission of Power: Its Present Position and Advantages. By Paget Higgs, LL.D., Dr. Sc. Crown 8vo. *Spons.* London. 3s.

Encyclopædia. Spons' Encyclopædia of the Industrial Arts, Manufactures, and Commercial Products. Edited by G. G. André, F. G. S. Assoc. Inst. C. E. (To be completed in Five Divisions.) Division I.—Containing Acids—Alcohol—Alkalies—Alloys—Alum—Arsenic—Asphalt—Assaying—Beverages, &c. Super-royal 8vo. *Spons.* London. 13s. 6d.

Engineers' Manual. A Manual for Railroad Engineers and Engineering Students. Containing the Rules and Tables needed for the Location, Construction, and Equipment of Railroads, as built in the United States. By George L. Vose. With 165 woodcuts and 31 large Plates. A new revised edition. Boston. *Lee & Shepard.* $12.50.

Expert Testimony: Its use and abuse. S. Snowden Bell. Philadelphia. 8vo. *Rees, Welsh & Co.* $1.00.

Graphics for Engineers. Part III. Arches in Wood, Iron and Stone. Prof. Greene. 8vo. New York. *Wiley.* (Announcement.)

Locomotive Engineer, Fireman and Engine Boy; comprising an Historical Notice of the Pioneer Locomotive Engines and their inventors, with a Project for the Establishment of Certificates of Qualification in the Running Service of Railways. Michael Reynolds. Cr. 8vo. *Crosby Lockwood.* 4s 6d.

Mechanics. C. Tomlinson (Weales' Series). New ed., 12mo. London. *Crosby Lockwood.* 1s. 6d.

Meteorology. The Nottingham —— for the past 12 years, 1867 to 1878 inclusive. From Diurnal Observations by M. Ogle Tarbotton; to which are added Rainfall Tables from several localities on the Trent Watershed. Roy. 8vo. *Spons.* London. 1s. 6d.

Military Prize Essay, 1879. Clayton (Captain Emilius). Field Intrenching; its Application on the Battlefield and its Bearing on Tactics. With Plates. 8vo. London. *W. Mitchell.* 2s. 6d.

Mining, Mining Machinery and Coal. List of Books upon these subjects, *Henry Carey Baird & Co.* Philadelphia.

Parks and Gardens of Paris. W. Robinson, F.L.S. With numerous Illustrations. 8vo. *Macmillan.* London (cheaper issue). 18s.

Railroad Accidents; Notes upon—. Charles Francis Adams, Jr. 12mo. New York. *Putnams.* $1.25.

Rainfall—British, 1878. On the Distribution of Rain over the British Isles during the year 1878, as observed at about 2,000 Stations in Great Britain and Ireland. G. J. Symons. 8vo. London. *Stanford.* 5s.

Railway System—The Index to our Railway System and our Leading Lines: A Comprehensive Analysis of Railway Property, 1878–79. No. 3. Wm. Fleming. London. 8vo. *McCorquodale*, 2s. 6d.

Sanitary Engineering. Report of the Proceeding of the District Meeting of Municipal and Sanitary Engineers and Surveyors held at the Town Hall, Wrexham, June 21st, 1879; Discussion on Shone's Patent Pneumatic Sewerage System. 4to. Discussion, fcap. *Brayley and Bradley* (Wrexham). *Spons.* London. 1s.

Science, Half-hour Recreations in Popular—. Second Series, uniform with the First Series, containing: Transmission of Sound by the Atmosphere, by John Tyndall; Gigantic Cuttle-Fish, by Saville Kent; The Glacial Epoch of our Globe, by Alexander Braun; The Sun and the Earth, by Prof. Balfour Stewart; The Ice Age in Britain, by Prof. Geikie; Plant Life in the Sea, by L. Kny; The Telephone and the Phonograph, by Prof. F. G. Garbit; The Use and Abuse of Food, Ozone, Dew; The Levelling Power of Rain, by Richard A. Proctor; The Succession of Life on the Earth, by Prof. W. C. Williamson; What the Earth is Composed of, by Prof. Roscoe; Notes on Tree Growth, by Prof. Asa Gray; Science and War, by H. Baden Pritchard; Existence of Glacial Action upon the Summit of Mt. Washington, N. H., by Prof. C. H. Hitchcock. One vol., large 12mo. Boston. *Estes & Lauriat.* $2.50.

Sewerage. Discussions on Isaac Stone's Pneumatic Sewerage System, by Engineers, Surveyors and Medical Doctors, convened under the Auspices of the "Sanitary Register," held in the Town Hall, Wrexham, July 19, 1879, under the Presidency of Dr. Lory Marsh. Roy. 8vo "*Guardian*" *Office* (Wrexham). *Spons.* London. 6d.

Sewers and drains of populous districts, by Col. J. W. Adams. New York. *Van Nostrand.* (Announcement.)

Thames Traffic. Report, evidence, maps. *British Govt. Publication.* London. 8s.

Thermodynamics. Prof. Henry T. Eddy. 18mo. (No. 45. Science Series). *Van Nostrand.* New York. $0.50.

Tunneling—Practical Tunneling, explaining in detail the setting out works, shaft sinking, heading driving, ranging lines, leveling under ground, sub-excavating, timbering, construction of brickwork of tunnels, with labor required for and cost of various portions of the work. By Frederick Walter Simms, C E. 3d ed., rev. and extended with chapters illustrating the recent practice at St. Gothard, Mt Cenis and other modern works. By D. Kinnear Clark, C.E. 8vo, illus. *Van Nostrand.* New York. $7.50.

Water—Analysis of Water. J. A. Wanklyn and E. T. Chapman. 5th ed., cr. 8vo. London. *Trubner.* 5s.

———. Address upon Water Economy, delivered at the Anniversary Meeting of the Sanitary Institute, July 10th, 1879, His Grace the Duke of Northumberland in the chair. G. Symons. Cr. 8vo, pp. 23. *Stanford.* London. 1s.

———; Power of Water. J. Glynn. New ed., 12mo. (Weales' series.) *Crosby Lockwood.* London. 2s.

———; National Water Supply, Sewage and Health. Annual Conference, Society of Arts, Adelphi, held Thursday and Friday, the 15th and 16th May, 1879. Imp. 8vo. *Bell and Sons.* London. 1s. 6d.; 2s.

Wave and Vortex Motion. Thomas Craig. 18mo, (No. 43, Science Series). *Van Nostrand.* New York. $0.50.

Weights; Tabulated Weights, of Angle, Tee, Bulb, Round, Square and Flat Iron and Steel, and other Information for the use of Naval Architects and Shipowners. By Chas H. Jordan, Mem. Inst. N.A., Surveyor to the Underwriters' Registry for Iron Vessels. Third Edition, rev. and enl., royal 32mo, cloth. *Spons.* London. 2s. 6d.

Wood Engraving—Practical Hints. For the instruction of reviewers and the public. W. J. Linton. 4to. *Lee & Shepard.* Boston. $0.50.

ADDITIONS TO

LIBRARY AND MUSEUM.

From Administration des Ponts et Chausées, Paris:

Annales, May, June and July, 1879.

List of Members Ponts et Chausées.

From American Academy of Arts and Sciences, Boston:

Proceedings from May 1878 to May 1879.

From American Chemical Society, P. Cassamajor, Secretary, New York:

Proceedings of the Society. Vol. 1. Nos. 4 and 6.

From American Institute of Mining Engineers, Prof. Thomas M. Drown, Secretary, Easton, Pa.:

The Tessie Gas Producer. A. L. Holley.

On some curious phenomena in making a Test of Bessemer Steel. Wm. Kent.

Accidents in the Comstock Mines and their relation to deep mining. John A. Church.

On the use of determining Slag densities in Smelting. Thomas Macfarlane.

The Antimony deposits of Arkansas. Charles E. Wait.

Discussion of Charles B. Dudley's paper on Steel Rails, read at the Lake George Meeting, October, 1877. By R. W. Hunt, W. R. Jones, T. Egleston, A. L. Holley, W. Metcalf, Wm. Kent, D. Torrey, H. M. Howe, C. E. Stafford, R. W. Raymond, W. E. C. Coxe. A. S. McCreath and Wm. P. Shinn.

Note on the Wear of Iron Rails. W. E.C. Coxe.

On an apparatus for Testing the resistance of metals to repeated shocks. Wm. Kent.

Pittsburgh—Its resources and surroundings. Wm. P. Shinn.

Proceedings of the Pittsburgh Meeting, May 13, 1879.
Regenerative Stoves, a sketch of their history and notes on their use. John M. Hartman.
Sketches of the New Mining District at Sullivan, Maine. C. W. Kempton.
The working of the three Hearths at the Cedar Point Furnace, Port Henry, N. Y. T. F. Witherbee.

From George D. Ansley, City Surveyor, Montreal:

Our Health and our Diseases; condition of Montreal in a Sanitary point of view. F. P. Mackelan, Montreal.

From Argentine Scientific Society. Don Felix Amoretté, Secretary, Buenos Ayres:

Annales, June and July, 1879.

From Board of Water Commissioners, Toronto. Canada:

Annual Reports of the Board for 1875, 1876, 1877 and 1878.

From Boston Public Library, Boston:

Twenty-seventh Annual Report of Boston Public Library.

From Hon. Allan Campbell, New York:

Report of the Department of Public Works, quarter ending March 31, 1879.

From E. S. Chesbrough, Chicago:

Third Annual Report Department of Public Works of Chicago.

From Civil Engineers' Club of the Northwest. L. P. Morehouse, Secretary, Chicago:

Proceedings of the Club.
Metric System.
Memorial of William H. Clarke.
Superstructure of the Glasgow Bridge.
Proposed Constitution and By-Laws by Committee on Reorganization.

From Prof. John Collet, Indianapolis, Ind.:

Eighth. Ninth and Tenth Annual Report of the Geological Survey of Indiana, made during the years 1876-77-78. E. T. Cox, Indianapolis, 1879.

From Joseph P. Davis, City Engineer, Boston:

Third Annual Report of the Boston Water Works.

From Maj. George W. Dresser, Secretary of Society of Gas Lighting, New York:

Transactions of the Society for 1877.

From Essayons Club, Corps of Engineers. U. S. A., W. M. Black, Secretary. Willetts Point, N. Y.:

Papers read before the Club during the winter 1878-79. as follows: XLV, Useful Tables for finding Specific Gravity. Lieut.-Col-Heger. XLVI—Notes on the use of Logarithms. H. S. Palfrey. XLVII—Testing of medium and high tension fuses. Gen. Abbot.

From Desmond Fitzgerald, Brookline, Mass.:

Third Annual Report of the Boston Water Works.

From Charles E. Fowler, City Surveyor, Hartford, Conn.:

Annual Reports of the Street Department of the City of New Haven, for 1876, 1877, and 1878.

From the Imperial College of Engineering, Henry Dyer, Principal, Tokio, Japan:

Reports of the Principal and Professors from 1873 to 1877.

From the Imperial and Royal Legation of Austria:

Beiträge zur Beleuchtung der allegemein Verhältnisse der Oesterreichischen Eisenbahnen.

From the Imperial Technic Society, Prof. Paul Panayeff, Director, Moscow, Russia:

Notes of the Society. Part 6 (Russian).

From the Institution of Civil Engineers, James Forrest, Secretary, London:

Minutes of Proceeding. Vol. LVII.
List of Members of the Institution, July 2, 1879.
Abstracts of papers in foreign Transactions and Periodicals. Vol. LVII. Session 1878-79. Part 3.
Excerpt from Minutes of Proceedings. Edited by James Forrest, as follows:
- Dioptric Apparatus in Lighthouses for the Electric Light. James T. Chance
- The Electric Light applied to Lighthouse Illumination. James N. Douglas.
- Description of Several Bridges erected in Switzerland. Jules Gaudard.
- Description of Machinery for the production and transmission in the larger Factories of East Lancashire and West Yorkshire. George W. Sutcliffe.
- Strength and elasticity of Materials. Wm. J. Millar.
- Dock Gates. Adam F. Blandy.
- The Improvement of the Bar of Dublin Harbor by Artificial Scour. John P. Griffiths.
- A Search for the Optimum System of Wheel Teeth. Edward Sang.
- Street Carriageway Pavements. George F. Deacon.
- Wood as a Paving Material under Heavy Traffic. Osbert H. Howarth
- Discussion on the two foregoing subjects.
- Experiments on the Filtration of Water. George Higgins.

From the Iron and Steel Institute, J. S Jeans, Secretary, London:

Journal of the Institute, No. 1. 1879.

From Henry F. Kane, C. E., New York:

Address to the Members of the New York Exchange, by Henry F. Kane, On the Practicability of permanently maintaining several feet increased depth over the Sandy Hook Bar, and otherwise improving the Channel,

From Charles Latimer, Cleveland, O.:

The French Metric System, or the Battle of the Standards. (Several copies.)

From Hon. R. C. McCormick, Washington, D. C.:

Our Success at Paris in 1878. R. C McCormick. New York, 1879.

From W. H. McFadden, Philadelphia:

Annual Report of the Chief Engineer of the Water Department of the City of Philadelphia for 1878.

From Midland Institute of Mining, Civil and Mechanical Engineers, Joseph Mitchell, Secretary, Barnsley, England:

Transactions. November, 1878. February, March, May and July, 1879. Vol. VI, Part XLVI.

From New York Meteorological Observatory, Daniel Draper, Director, New York:

Abstracts of Registers from Self-Recording Instruments. June and July, 1879.

From North of England Institute Mining and Mechanical Engineers, Theo. Wood Bunning, Secretary, Newcastle-on-Tyne, England :

Transactions. April, May and June, 1879.

From the Publishers Revue Générale des Chemins de fer, Edgar Monjean, Secretary. Paris :

Revue Générale des Chemins de fer. May and June, 1879.

From Philadelphia and Reading Coal and Iron Co. Philadelphia :

Diagram and Tables showing the Annual Production of Anthracite Coal in Pennsylvania since 1820, and the amount produced from each region.

From Royal United Service Institution, Capt. B. Burgess, Secretary, London :

Appendix to Vol. XXII of the Journal of the Institution.

Vol. XXIII, Journal of the Institution, No. C. Extra number.

From Société des Ingénieurs Civils, M. Mallet, Secretary, Paris :

Mémoires de la Société. November and December, 1878. January, February, March and April, 1879.

From R. H. Thurston, Hoboken, N. J. :

Friction and Lubrication. Prof. R. H. Thurston. New York. 1879.

Mechanical and Physical Properties of the Copper-Tin Alloys. Prof. R. H. Thurston. Washington, 1879.

From United States Light House Board, Washington, D. C.:

List of Beacons, Buoys. Monuments and other Day Marks in the First Light House District, corrected to July 1, 1879.

From Jerome B. Ward, Newark, N. J. :

Report on Additional Water Supply for the City of Newark, N. J. By J. James R. Croes and George W. Howell. March 6th, 1879. (Several copies.)

From Hon. A. A. Wagstaff, New York :

Annual Report of the Superintendent of Public Works, State of New York, for 1878. B. S. W. Clark.

Annual Financial Report of the Auditor of the Canal Department of the State of New York for 1878. G. W. Schuyler.

Second Annual Report of the Superintendent of State Prisons of the State of New York. Louis D. Pilsbury.

Report of the Board of Commissioners of Pilots, December 31st, 1878.

Communication from the Superintendent of State Prisons relative to the Contract System in the State Prisons. L. D. Pilsbury.

Communication from the Acting Chief of Engineers, U. S. A., relative to the Pier and Bulkhead Lines of New York Harbor. Gen. H. G. Wright.

A Proposed New City Park for the extreme Eastern portion of New York. Wm. J. Fryer, Jr.

The Necessity to Commerce of Cheap Water Communication between the West and East. An Address to the Farmers of Ohio, Indiana and Illinois.

From Gen. H. G Wright, Chief of Engineers, U. S. A.. Washington, D. C.:

Reports upon the Specimens obtained from Borings made in 1874 between the Mississippi River and Lake Borgne, at the site proposed for an outlet for flood water. Prof. Eugene W. Hilgard and Dr. F. V. Hopkins.

On the Use of the Barometer on Surveys and Reconnaissances. Lieut. Col. R. S. Williamson.

Eleventh Report upon the Improvement of the South Pass of the Mississippi River. Capt. M. R. Brown. (Copies for distribution.)

From A. F. Wrotnowski, New Orleans :

Topographical and Drainage Map of New Orleans and Surroundings.

ANNOUNCEMENTS.

At the meeting of the Society of October 1st, the paper by James D. Burr, member of the Society, subject, "The Construction of the Railroad over the Raton Mountains," will be read and discussed.

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Discussion on each of these subjects is especially invited. The Secretary will forward the advance copies to those who inform him of their desire to discuss. The discussions may be presented verbally or sent to the Secretary, who will read them for the authors.

The Twenty-seventh annual meeting of the Society will be held at its rooms in New York, on November 5th, 1879, at 10 A.M.

The following resolution was adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications:

Whereas, the metric system of weights and measures is now extensively used abroad, and whereas it is desirable that the relation

of the units of differing systems be made familiar to all by comparison:

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LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

		Date of Election.
CUNNINGHAM, JAMES H.	Engineer and Proprietor, Milwaukee Bridge and Iron Works, Milwaukee, Wis.	August 6, 1879.
FINNEY, FREDERICK N.	General Manager, Wisconsin Central Railroad, Milwaukee, Wis.	Sept. 3, "
PROUT, HENRY G.	(Elected Associate, Nov. 6, 1872), 12 Barclay street, New York	" " "
TITLOW, JOHN M.	Ass't Engineer, Department of Surveys, E. Entrance, City Hall, Philadelphia, Pa.	August 6, "

CHANGES AND CORRECTIONS.

MEMBERS.

ALLEN, C. FRANK.....Engineers' office, New Mexico & Southern Pacific Railroad, Las Vegas, New Mexico.

MORSS, FOSTER.....Engineer Shenandoah Valley Railroad, Berryville, Va.

WHITNEY, JOSEPH.....Cambridgeport, Mass.

JUNIOR.

LUCAS, D. JONES.....Box 405, Lewiston, Maine.

RESIGNATION.

STEELE, J. DUTTON.....September 5th, 1879.

DEATH.

COLBURN, WARREN.....Elected Member, March 18th, 1868. Died September 16th, 1879.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. V, October, 1879.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

October 1st, 1879.—The Society met at 8 p. m., William H. Paine in the chair. Ballots were canvassed, and Thomas M. Cleeman, of Philadelphia, Pa., and Irvin John, of New York, were declared elected members. The vote was canvassed on resolutions submitted to letter ballot, with the following result :

On the resolution :

Resolved, That a standing committee of seven, representing different sections of the country, be appointed from the American Society of Civil Engineers, who shall examine into the entire subject of the preservation of timber, and report to the Society from time to time, and who shall collect such samples and data as they may be able, to aid in determining the relative values of the different woods, both preserved and unpreserved, in ordinary use in various parts of the country.

There were 149 yeas and 7 noes.

This resolution was thereupon declared adopted.

On the resolution :

Resolved, That a committee of seven members of the Society be appointed by the Board of Direction to devise and report a uniform system for tests of cement.

There were 147 yeas and 9 noes.

This resolution was thereupon declared adopted.

The death, on September 16th, 1879, of Warren Colburn, member of the Society, was announced, and the Chairman was authorized to appoint a committee to prepare a memoir of the deceased.

The following amendments to the Constitution were submitted :

Amendment to Article XXII., proposed by William E. Worthen, L. B. Ward, Charles Macdonald, J. J. R. Croes, and Stevenson Towle :

At the end of Article XXII. insert : "On and after the fifth day of November, 1879, Past Presidents of the Society shall be Life Members, entitled to all the privileges of members without the payment of Annual Dues.

Amendment to Article XXXIII., proposed by William P. Shinn, William Metcalf, Reuben Miller, C. Vandervoort Smith, and William H. Paine :

To amend Article XXXIII. so that the amended article shall read as follows :

ARTICLE XXXIII.—Proposed amendments to this Constitution must be submitted in writing, signed by not less than five members, on or before the first Wednesday in October, and then sent by letter to the several members of the Society, at least twenty-five days previous to the Annual Meeting. Such amendments shall be in order for discussion *and amendment* at such Annual Meeting, and *with such amendments thereto as may have been approved by a majority vote of the Annual Meeting,* shall be voted upon by letter ballot, the vote to be counted at the first regular meeting in February. An affirmative vote of two-thirds of all ballots cast shall be necessary to secure the adoption of any amendment.

The words in italics constitute the proposed amendment ; otherwise the article is unaltered.

These amendments will be in order for discussion at the Annual Meeting, and afterwards will be voted upon by letter ballot.

The discussion on the paper by Edward P. North on "Construction and Maintenance of Roads" was resumed and participated in by E. B. Van Winkle, J. J. R. Croes, E. R. Andrews, E. Yardley, J. C. Post, and E. P. North.

A paper by James D. Burr, subject "The Construction of the Atchison, Topeka & Santa Fe Railroad over the Raton Mountains, and the performance of Locomotives on its steep grades," was read by the Secretary and discussed by J. Foster Flagg (by letter), E. Yardley, C. E. Emery, and E. P. North.

OF THE BOARD OF DIRECTION.

AUGUST 4TH, 1879.—Applications for membership were considered.

SEPTEMBER 2D, 1879.—Applications for membership were considered. The Board of Censors to award the Norman Medal for the present year were appointed as follows : E. S. Chesbrough, Charles Paine, and C. Shaler Smith. Resolutions for appointment of standing committees were considered and ordered to be submitted to vote by letter ballot. Financial matters and arrears due from members were considered, and appropriations were made.

OCTOBER 1ST, 1879.—Applications for membership were considered. The distribution and exchange of publications were acted upon. The

publication of a Society paper in a journal, without giving credit to the Society, was brought up, and action taken, Preparation was made for the Annual Report of the Board. The report of the Nominating Committee was received, and it was ordered that a ballot should be prepared and issued in accordance with the By-Laws. Appropriations were made.

THE NORMAN MEDAL.

The following rules have been adopted by the Board of Direction, with the approval of the donor of the Medal Fund, George H. Norman, Member and Fellow of the Society:

CODE OF RULES
FOR THE
AWARD OF THE NORMAN MEDAL.

I.—Competition for the Norman Medal of the American Society of Civil Engineers shall be restricted to Members of the Society.

II.—There shall be one gold medal, and only one, struck for each and every fiscal year of the Society, and awarded as hereinafter provided. The dies therefor shall be with the Superintendent of the United States Mint at Philadelphia, in trust exclusively for the above purpose. Such medal shall be of a cost equal to the annual interest received upon $1,000 00 of the Consolidated Stock of the City of New York, Certificate No. 179, of the additional new Croton Aqueduct Stock of the City of New York, authorized by an act of the Legislature of the State of New York, Chap. 230, passed April 15th, 1870, dated November 17th, 1873, now held in trust by the Treasurer of this Society, and so held solely for this purpose, and shall be executed upon his order.

III.—All original papers presented to the Society by members of any class, during the year for which the medal is awarded, shall be open to the awards, provided that such papers shall not have been previously contributed in whole or in part to any other association, nor have appeared in print prior to their publication by the Society, nor have been presented to the Society in any previous year.

IV.—The Board of Censors to award the Medal shall consist of three members of the Society, to be designated by the Board of Direction. The Secretary of the Society shall act as Secretary to the Board of Censors.

V.—The medal shall be awarded to such paper as the said Board shall judge to be worthy of special commendation for its merits as a contribution to Engineering Science, not merely relatively as compared with others presented during the same year, but as exhibiting the science, talent, or industry displayed in the consideration of the subject treated

of, and for the good which may be expected to result from the discussion and the inquiry.

VI.—In case no paper presented during the year shall be deemed of sufficient value to receive an award, the amount of the interest of the fund for that year shall be expended by the Board of Direction in the purchase of books, to be offered as a premium for the second best paper in the next year in which more than one paper of sufficient value may be presented.

VII.—The medal year shall terminate on the first day of August, and the award shall be announced at the Annual Meeting in November.

VIII.—The Treasurer of this Society shall cause the medal to be prepared and delivered to, or deposited to the order of, the successful competitor, within two months after the Annual Meeting at which the same shall have been awarded.

ADDITIONS TO

LIBRARY AND MUSEUM.

From Administration des Ponts et Chausées, Paris:
Annales. August, 1879.

From American Chemical Society, P. Cassamajor, Secretary, New York:
Journal of the Society. Vol. 1. No. 7.

From Argentine Scientific Society, Don Felix Amoretti, Secretary, Buenos Ayres:
Anales. August. 1879.

From Hon. Allan Campbell, New York:
Report of the Department of Public Works of the City of New York, for the quarter ending June 30, 1879, with special report on the subject of Water Supply.

From O. Chanute, New York:
Blue and white Tracings of Sample Test Bars. Records of Tests, Iron and Steel, N. Y. L. E. and W. R. R. (Several copies.)

From Theodore Cooper, New York:
Report of the proceedings of the Interoceanic Canal Congress, held at Paris, May, 1879, and instructions given to Daniel Ammen and Civil Engineer A. G. Menocal, U. S. N.

From Department of the Interior, Washington, D. C.:
Report of the Commissioner of Education for the year 1877. (Two copies.)

From Charles E. Fowler, New Haven, Conn.;
City Year Book of New Haven, containing List of officers, messages of the Mayor, Reports of Departments, Public Documents and Miscellaneous papers from 1876 to 1878.

From George H. Frost, New York:
A comprehensive Treatise on the Water Supply of Cities and Towns. William Humber.

From E. T. Hall, New York:
Bulletin of the American Geographical Society. No. 4. 1878.

From Julius E. Hilgard, Assistant in charge United States Coast Survey, Washington, D. C.:
Report on Interoceanic Canals and Railroads between the Atlantic and Pacific Oceans. Charles H. Davis.
Methods and results—secular change of Magnetic Declination in the United States and at some foreign stations. Third edition.

From the Institute for the advancement of Technical Education, London,
Programme of Technological Examinations for 1880.

From the Institution of Civil Engineers, James Forrest, Secretary, London:
Charter, By-Laws and Regulations, and List of Members, Institution of Civil Engineers, August 2d, 1879.
Minutes of Proceedings. Vol. LVIII.
Abstracts of Papers in foreign Transactions and Periodicals. Vol. LVIII.
Session 1878–79. Part 4.
Excerpt from Minutes of Proceedings. Edited by James Forrest, as follows:
Description of a New Balance Bridge over the Royal Canal at Dublin. Bindon B. Stoney.
On Keeping Irrigation Canals clear of Silt. R. B. Buckley.
On the Street and Footwalk Pavements of Montreal, Canada, from the year 1842 to 1878. Percival W. St. George.
The Traveling of Sea Beaches. George U. Kinahan.

From the Institution of Mechanical Engineers, W. R. Browne, Secretary, London:
Proceedings of the Institute. June, 1879.

From M. Fero de Lesseps, Paris, France:
Proceedings of the International Congress on the Inter-oceanic Canal, held at Paris, May 15th to May 29th, 1879 (French).
The reality of a Ship Canal across the Isthmus of Panama. Lucien de Puydt (French).
International Company of the Columbian Ship Canal, founded in Paris, March 9th, 1864. Organized for the purpose of cutting a Ship Canal on a level without Locks or Tunnels, across the Isthmus of Darien.

From G. A. M. Liljencrantz, Chicago:
America's Climate. Graphical illustrations of the Daily Variationsof Temperature for one year, from July 1, 1878, to June 30, 1879. Sheets 1 and 2. G. A. M. Liljencrantz, C. E.

From E. P. Lull, Commander U. S. N., Washington, D. C.:
Reports of Explorations and Surveys for the location of a Ship Canal between the Atlantic and Pacific Oceans, through Nicaragua. 1872-73.

From the National Board of Health, Washington, D. C.:
Schedules of Questions for a Sanitary Survey of a City or Town.

From Simon Newcomb, Supt. American Ephemeris and Nautical Almanac, Washington, D. C.:
Astronomical Papers, prepared for the use of the American Ephemeris and Nautical Almanac. Vol. I., Part I. Tables of Eclipses.

From New York Meteorological Observatory, Department Public Parks, Daniel Draper, Director, New York:
Abstracts of Registers from Self-Recording Instruments. August, 1879.

From Charles Paine, Cleveland, Ohio:
Proceedings of Civil Engineers of the Northwest. August 5th, 1879.
Letter objecting to the proposed Constitution of Civil Engineers' Club of the Northwest.

From Ernest Pontzen, Paris, France:
Le Verre Trempé.

From the Royal Technical High school, Hanover, Germany:
Prospectus for 1879-80 (German).

From W. H. Schock, Engineer-in-Chief U. S. N. Bureau of Steam Engineering, Washington, D. C.:
Annual Report of the Chief of the Bureau of Steam Engineering
Report on the Herreshoff Boiler, submitted to the Navy Department January 12th, 1878.
Report of the Board to recommend a Standard Gauge for Bolts, Nuts, and Screw Threads for the United States Navy. May, 1878.
Speed Co-efficients of Screws of Vessels in the United States Navy.
Power Co-efficients of Engines of Vessels in the United States Navy.
Report on the two kinds of Coal submitted by the Chesapeake and Ohio Railroad Co.
Iron Manufacturers in Great Britain. Prof. R. H. Thurston.
Report on the Ashcroft Furnace Doors and Grate Bars.
Report on the Murphy Grate Bar.
Report on D. C. Green's System of Ventilation.
Report on Safety Valve Tests made at the United States Navy Yard, Washington, D. C., September, 1875.

From Société des Ingénieurs Civils, M. Mallet, Secretary, Paris, France:
Mémoires de la Société. May and June, 1879.

From United States Light House Board, Washington, D. C.:
List of Towers, Beacons, Buoys, Stakes and other Day Marks in the Seventh Light House District. Corrected to July 1, 1879. (Two copies)

From E B. Van Winkle, Topographical Engineer, Department Public Parks, New York:
Conditions of proposals for Constructing Sewer and Appurtenances in 134th Street, from 410 feet East of Willis Avenue to Brook Avenue, with Branch in Brown Place.
Conditions of proposals for Constructing Sewer and Appurtenances in 141st Street, from Alexander Avenue to Brook Avenue, with Branches in Alexander Avenue and Willis Avenue.
Form of agreement in Triplicate for the Construction of Drains on and for the Lands bounded by George Street on the north, Union Avenue and White's Lane on the east, Delmonico and Concord Avenues on the west, and thence southerly to Long Island Sound, in the 23d Ward of the City of New York.

From George E. Waring, Jr., Newport, R. I.
Excremental Diseases: Their causation and their prevention by Hygienic means. George E. Waring, Jr.

From A. R. Whitney, New York:
Two framed Photographs of the Third Avenue Elevated Railroad.

From the World's Fair Committee for 1883, W. H. C. Price, Secretary, New York:
The World's Fair Committee for the proposed World's Fair in the City of New York for 1883.
Address of the Committee to the people of the United States.

From Gen. H. G. Wright, Chief of Engineers, U. S. A., Washington, D. C.:
Official Army Register for 1879.

From other sources;
The American Catalogue, Vol. I, Authors and Titles; Part 4. Robbie—Z.
On the Molecular Changes produced in Iron by variations of temperature. Prof. R. H. Thurston.
New York Ore Separator Company.
The Manufacture of Steel. M. L. Gruner.
Railway Gauges, from the *London Times* of January 17th, 1873.
Proceedings of the National Narrow Gauge Railway Convention, held at St. Louis, Mo., June 19th, 1872.
A letter to the Rt. Hon. H. C. E. Childers, M. P., on Railway Gauges. W. W. Evans.
A letter on the Railway Gauge question, by B. H. Latrobe, with extracts from English Eegineers' reports to the British Government on Railway Gauges, published by W W. Evans.
The Street Railroads of the City of New York.
Railway Rolling Stock and discussion by W. R. Browne and W. A. Adams.
Time Tables, London, Chatham and Dover Railway, August, 1878.
Time Tables of London and Northwestern and other railways in connection, January, 1879.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

Date of Election.

CLEEMANN, THOMAS M.....340 South Twenty-first street, Philadelphia, Pa.....October 1st, 1879.

LEHNARTZ, FREDERICK W...United States Engineer's Office, Cascade Locks, Owasco Co., Oregon. August 6, 1879.

CHANGES AND CORRECTIONS.

MEMBERS.

BILLIN, CHARLES E.....Pencoyd Iron Works, 265 South Fourth street, Philadelphia, Pa.

FALCONNET, E. F.....Chief Engineer, Owensboro and Nashville Railroad, Nashville, Tenn.

FUNIAK, FRED. DE.....General Manager Louisville and Nashville Railroad, Louisville, Ky.

JAMES, JOHN C .....Chief Engineer Northwestern Grand Trunk Railroad, Battle Creek, Mich.

NICHOLS, O. F..... .....25 Wall street, Trenton, N. J.

PONTZEN, ERNEST.....4 Rue de Castellane, Paris, France.

STAUFFER, D. MC. N.....129 South Thirteenth street, Philadelphia, Pa.

STEPHENS, CLINTON F.....Resident Engineer, Texas and St. Louis Railroad, Texarkana, Ark.

YARDLEY, EDMUND.....104 East 20th Street, New York.

ASSOCIATE.

HARRIS, CHARLES M.....83 Cedar street, New York.

JUNIOR.

FRANCIS, HENRY N.....City Hall, Providence, R. I.

DEATHS.

VINTON, FRANCIS L.....Elected Member August 5th, 1868. Died October 6th, 1879.

TASKER, CHARLES A..... Elected Junior, November 4th, 1874. Died October 4th, 1879.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. V, November, 1879.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

October 15th, 1879.—The Society met at 8 p. m., Walter Katté in the chair. The paper by Max E. Schmidt, subject "The South Pass Jetties," published in Transactions for August, 1879, was discussed by J. Foster Flagg (by letter), and by Messrs. E. R. Andrews, O. Chanute, T. Cooper, W. Katté, T. J. Long, E. P. North and J. W. Putnam.

November 5th, 1879.—The Twenty-seventh Annual Meeting of the Society.—The Society met at 10 a. m., Vice President Albert Fink in the chair. The following members were present:

Messrs. Edward R. Andrews, George S. Baxter, John Bogart, Robert Briggs, O. Chanute, E. S. Chesbrough, Thomas C. Clarke, F. Collingwood. Theodore Cooper, Martin Coryell, J. J. R. Croes, Wilson Crosby, D. W. Cunningham, E. B. Dorsey, G. W. Dresser, Theodore G. Ellis, Charles E. Emery, Albert Fink, Clark Fisher, Edward A. Flint, A. Gordon, Bryant Godwin, G. Thomas Hall, Sullivan Haslett, A. L. Holley, William E. Kelley, George O. Knapp, Charles Latimer, G.

Leverich, W. W. Maclay, Edward Marsland, Charles C. Martin, Charles L. McAlpine, D. N. Melvin, William Metcalf, W. A. Nichols, Edward P. North, F. O. Norton, William H. Paine, Franklin C. Prindle. C. Vandervoort Smith, George C. Tingley, E. B. Van Winkle, W. W. Wilson, De Volson Wood, William E. Worthen and W. W. Wright.

George W. Dresser and Theodore Cooper were appointed Tellers of the ballots for officers.

The Annual Report of the Board of Direction was then presented, read by the Secretary, and on motion was accepted.

The Annual Report of the Treasurer was presented, read and accepted.

The Annual Report of the Finance Committee was presented, read and accepted.

The Report of the Library Committee on the subject referred to it at the last Convention, namely, whether some plan may not be adopted to enable members living away from New York to consult the books of the Library, under proper regulations to ensure their return and to prevent injury, was then presented, read and accepted.

A report from the Committee on Gauging of Streams was then read, accepted, and the Committee continued.

The Secretary presented a statement of the answers to the circular requesting suggestions as to the time and place for the next Annual Convention. After discussion, it was resolved that there should be issued to the Society a circular giving an abstract of the suggestions made on the subject, and that the determination of the place for the Convention should be submitted to letter ballot, restricting the vote to the three cities already suggested by the largest number of members, namely, St. Louis, Washington and San Francisco.

The Report of the Committee on the Exhibit of American Engineering at the Paris Exposition was then presented, read by Edward P. North, accepted, and the Commission discharged.

A report from the Centennial Commission of the Society was then presented by the Chairman, Theodore G. Ellis, to the effect that the Commission had been continued from year to year, in the hope that the Chairmen of the Sub-Committees, on various divisions of Engineering Exhibits would prepare reports. Only two, however, had been presented, those on Lighthouses and on Rivers and Harbors, and as there was no probability of further reports, the Commission asked to be discharged. The report was accepted and the Commission discharged.

The Committee on Method of Nominations then presented a verbal report through the Chairman, J. J. R. Croes. On motion, it was resolved that the Committee be continued, and that the former report made by it be printed and sent to the members of the Society for discussion and suggestion.

The Committee on Quarters for the Society presented a report, which was, on motion, accepted, the Committee continued, and instructed to

report, as soon as practicable, by letter to the Society, what was considered a feasible plan for procuring a suitable building to belong to the Society.

The tellers of the ballots for officers then reported the canvass of the votes, and the following named members were declared elected officers of the Society for the ensuing year: President, Albert Fink; Vice-Presidents, James B. Francis and Octave Chanute; Secretary and Librarian, John Bogart; Treasurer, J. James R. Croes; Directors, William H. Paine, C. Vandervoort Smith, Charles Hermany, Edgar B. Van Winkle and Gouverneur K. Warren.

The following proposed Amendment to Article XXII. of the Constitution was considered:

At the end of Article XXII, insert: "On and after the fifth day of November, 1879. Pas Presidents of the Society shall be Life Members, entitled to all the privileges of members without the payment of Annual Dues."

After discussion, it was resolved that this proposed amendment be submitted to letter ballot without comment.

The following proposed Amendment to Article XXXIII. of the Constitution was considered:

To amend Article XXXIII, so that the amended article shall read as follows:

ARTICLE XXXIII.—Proposed amendments to this Constitution must be submitted in writing, signed by not less than five Members on or before the first Wednesday in October, and then sent by letter to the several Members of the Society, at least twenty-five days previous to the Annual Meeting. Such amendment shall be in order for discussion *and amendment* at such Annual Meeting, and *with such amendments thereto as may have been approved by a majority vote of the Annual Meeting*, shall be voted upon by letter ballot, the vote to be counted at the first regular meeting in February. Any affirmative vote of two-thirds of all ballots cast shall be necessary to secure the adoption of any amendment.

The words in italics constitute the proposed amendment; otherwise the article is unaltered.

After discussion, it was resolved that the proposed amendment be approved by this meeting.

The result of the canvass of the ballots for membership was then announced, and the following candidates were declared elected members: Daniel Bontecou of New York, Alexander Dempster of Pittsburgh, Pa., Horace Loomis of New York, and James Hart Reno of Pittsburgh, Pa.

The suggestion made in the report of the Board of Direction as to the advisability of changing the day of the Annual Meeting and the date of termination of the Society year was discussed, and the Secretary was requested to present the subject for discussion at the next Convention.

On motion, the thanks of the Society were presented to the officers for the past Society year.

The Board of Censors to award the Norman Medal and Book Prize then presented its report through E. S. Chesbrough.

THE

ANNUAL REPORT OF THE BOARD OF DIRECTION,

FOR THE YEAR ENDING NOVEMBER 5, 1879.

PRESENTED AND ACCEPTED AT THE ANNUAL MEETING OF THAT DATE.

The Board of Direction presents the following Report for the term from November 6th, 1878, to November 5th, 1879:

On November 6th, 1878, the membership in the Society was—

Honorary Members, resident,	2 ;	non-resident,	4 ;	Total				6
Corresponding Members,....		"	3	"				3
Members, resident.....	120	"	334	"			454	
Associates, "	4	"	13	"			17	
Juniors, "	8	"	49	"			57	528
Making.....	134		403					537
Fellows, 67—of whom 10 Members and 1 Honorary Member are included above, leaving.....								56
Total connected with the Society November 6th, 1878.....								593

At the present time the membership is—

Honorary members, resident,	2 ;	non-resident,	4 ;	total				6
Corresponding Members....		"	3	"				3
Members, resident.....	119	"	345	"			464	
Associates, "	5	"	13	"			18	
Juniors "	8	"	46	"			54	536
Making.....	134		411					545
Fellows, 67—of whom 10 members and 1 Honorary Member are included above, leaving.....								56
Total connected with the Society November 5th, 1879.....								601

The increase during the year has been—

Members admitted	28
Associates admitted.....	2
Juniors admitted.....	3
Fellows admitted	1
Total increase.....	34

The decrease during the year has been—

Members died.....	8 ;	resigned.....	10			
Associates "	—	"	—	Transferred to Members. ...		1
Juniors "	1	"	—	" "		5
Fellows "	1	"	—	" "		
Total died....	10 ;	resigned.....	10 ;	transferred		6

On November 6th, 1878, there were, as stated in the last annual report, 6 proposals pending; 44 proposals have been received during the year; 31 candidates have been elected members, of whom 5 were transferred from Juniors

and 1 from Associates ; 2 candidates have been elected as Associates, and 3 candidates have been elected as Juniors ; 28 persons have qualified during the year as Members, 2 as Associates, 3 as Juniors, and 1 as Fellow ; 3 candidates elected as Members during the year have not yet qualified ; there are 13 proposals now pending.

23 meetings of the Society were held during the year, one of which was the Eleventh Annual Convention ; all the sessions of the Convention, including the business meeting, being counted as one meeting of the Society. Meetings have been held on the first and third Wednesdays of each month, except the third Wednesday of August. 13 meetings of the Board of Direction have been held during the year.

The Eleventh Annual Convention was held at Cleveland, Ohio, June 17th, 18th, and 19th, 1879. During this time and after the close of the Convention, many works of engineering interest were visited both in Cleveland and its immediate vicinity, and also at Leavittsburgh, at the Mahoning Valley coal-fields, at Youngstown, Pittsburgh, the Davis Island dam, the Edgar Thomson Steel Works, the Bradford oil district, and at Niagara Falls. Full reports of the Convention have been published in the Proceedings.

The answers to a circular issued to the Society, requesting suggestions as to the place and time for the next convention will be submitted at this meeting.

Reports made during the year have been as follows :

By the Board of Direction.—The Annual Report for the year ; also a report as to the publication of papers, a report as to arrears of dues from members, and a report as to designation of engineers to attend turbine tests at Holyoke.
By the Finance Committee.—2 reports.
By the Library Committee.—A report, embodying the changed rules for the award of the Norman Medal.
By the Treasurer.—His annual report, and also frequent financial statements to the Board.
By the Secretary.—Monthly Reports to the Board.
By the Centennial Commission of the Society.—1 repor .
By the Committee on Exhibit at Paris.—2 reports.
By the Committee on Tests of American Iron, Steel, and Other Metals.—2 reports.
By the Committee on Gauging of Streams.—1 report.
By the Committee on Quarters for the Society.—1 report.
By the Committee on Uniform System of Railroad Accounts.—2 reports.
By the Committee on the Resistances of Railway Trains.—1 report.
By the Committee on Method of Nominations.—1 report.

The Treasurer's Report and the Report of the Finance Committee will be submitted at this meeting.

At the last annual meeting, the Committee on Resistances of Railway Trains made a final report, and asked to be discharged, which was done.

At the last convention the Committee on Uniform Accounts and Returns of Railroad Companies made a final report, and asked to be discharged, which was done.

The other committees referred to in the last report of the Board are still existing, and reports will be expected from them at the present annual meeting. These are the Centennial Commission of the Society; the Committee on Tests of American Iron, Steel, and Other Metals; on Gauging of Streams; on Quarters for the Society; on Methods of Nominations; and on the Exhibition at Paris.

Resolutions were offered at the last Annual Convention for the appointment of a Committee on the Preservation of Timber, and a Committee on a Uniform System for Tests of Cement.

These resolutions have been submitted to letter ballot, and approved. The Board is now in correspondence with members in reference to the persons to serve on these committees.

At the Annual Convention the following resolution was adopted:

"That the Library Committee be requested to report whether some plan may not be adopted to enable members living away from New York to consult the books of the library, under proper regulations to insure their return, and to prevent injury."

The Library Committee will report on this subject at this meeting.

A list of the papers and discussions published during the year, also of those presented in addition to those published, and also of the contents of Proceedings, will be given in an Appendix.

The library has been increased during the year by the following additions:

Number of Books, bound	78
" " unbound	102
" Pamphlets	387
" Maps	9
" Plans	15
" Photographs	30
" Drawings, Specifications, Models and Specimens	38

These do not include the magazines and papers contributed to the Society by publishers or received in exchange for the Transactions, a list of which is given in an appendix.

The present state of the Library is about as follows:

Books and Pamphlets	8 054
Manuscripts	95
Maps, Plans, Drawings, Charts, Photographs and Engravings	1,966
Models and Specimens	218

At the last Annual Meeting a codification of the Constitution and By-Laws, together with a number of proposed amendments were discussed. These were afterwards submitted to a letter ballot of the Society and the Constitution and By-Laws, as finally adopted, have been printed in pamphlet form.

Two amendments have been submitted for debate at the present Annual Meeting, one relating to the Past Presidents of the Society, and the other relating to the method of amending the Constitution.

In this connection, it has been suggested by a number of members, that the date of the Annual Meeting is particularly inconvenient, coming, as it does, the day after the date of the elections in quite a number of States. The Secretary has been informed by several members that their attendance at that day would be inconvenient, and in some cases, impracticable, and a change in the date of the Annual meeting might be discussed, and a more desirable day suggested.

The Board suggests that the fiscal year shall end on December 31st; that the Annual Meeting, election of officers and reception of reports be held on

the 3d Wednesday of January, and that the term of office should begin on the day of election.

In the last Annual Report the Board called attention to the large number of members in arrears for their dues. In its judgment the interests of the Society demanded that measures should be taken to determine whether the dereliction was due to inability to pay or to indifference, and if the latter was the cause, that the connection of the delinquents with the Society should cease. In accordance with these views, the Board, on April 30th, in compliance with the provisions of the Constitution, passed the following resolution :

"*Resolved*, That the Secretary be directed to notify all members in arrears "that unless the dues for the current Society year, beginning November 6th, "1878, are paid before November 5th, 1879, they will cease to be members.

"Also, that members who are in arrears for more than the dues for the "current year, be notified that their dues for years previous to the current "year are still to be paid, and that payment of the same will be required, "unless good reason to the contrary, in compliance with the provisions of "Article XXXII of the Constitution, be assigned before November 5th, 1879."

In accordance with this action, there were sent, on May 1, 1878, to each member whose dues were not then paid, a copy of the above resolution, the formal notice (Form C) prescribed by the Constitution for use in case of non-payment of dues and a copy of the Articles of the Constitution relating to this subject.

Since that time a number of members have paid their dues in full ; others have paid the dues for the past year only, thus retaining their membership under the resolution quoted above; others have written in reply expressing their intention or desire to pay as soon as possible, and a large number have made no response whatever.

The necessity of preparing this report previous to the Annual Meeting and the probability that a number of members may give attention to this matter at the time of the meeting, prevents the Board from giving a final statement on the subject. After this meeting a full statement will be prepared and presented in a future report. It is apparent, however, that there will be quite a number of members whose names have been on the roll of the Society for some time past, whose membership will cease.

While the Board regrets the apparent decrease in membership, caused by this action, it feels that it is necessary to the prosperity of the Society that it should be distinctly understood that membership of the Society carries with it the obligation to contribute to its support, and that members cannot be carried on its rolls unless they bear their burdens equally with their fellows.

The subject of the conditions of award for the Norman Medal has been carefully considered by the Library Committee and by the Board and the donor of the medal, Mr. George H. Norman, member and Fellow of the Society, has been fully consulted.

No paper was presented in competition for the medal either the last or the present year, and it was felt to be for the best interests of the Society and due also to the donor of the medal that a different plan for its award should be adopted.

With his full concurrence the code of rules for this award has been modified, and competition is now extended to all papers conforming to the rules, presented to the Society during each year. The modified rules have been published for several months with the Proceedings. The Board of Censors to award the medal for this year, Messrs. E. S. Chesbrough, Charles Paine and C. Shaler Smith are expected to report at this meeting.

The Board has issued a list of topics upon which original papers, illustrating the experience of the writers, are requested. The attention of members of the Society is called to the great desirability of the presentation of papers by them upon subjects of engineering interest. Discussions of the papers presented are also in many cases essential to a full development of professional information on the subjects of those papers. Early information is now given, by notification to the members, of the papers to be read at each meeting and advance copies are sent to such members as are designated by the authors of the papers as specially qualified to take part in the discussions, and also to other members who desire such advance copies. The result of this practice has been not only to secure more extended discussion, but also to have the paper and its discussions presented at the same time, the Secretary reading the discussions sent him by persons not able to be present.

The Transactions of the Society are now issued up to date, the Number for October, 1879, having been sent out some time since. At the time of the last Annual Report one year ago, the Transactions were much behind. The reasons, altogether financial, for that state of things were explained in that Report. It has been found possible during the past year to publish not only the twelve monthly Numbers, but enough in addition to bring the issues to date in their regular sequence. This has added considerably to the labor of editing and supervising the publications, but it is the belief of the Board that with the systematic and business-like management of the financial affairs of the Society now in operation the future issues of its publications can be regularly made.

In but one previous year of its history has the Society lost so many of its members by death. The decease of eight members, one Junior and one Fellow, is announced, as follows :

Alfred W. Craven, Past-President and one of the original incorporators of the Society, November 5th, 1852, died March 27, 1879.

Robert G. Hatfield, elected Member December 4, 1867, who died February 15, 1879.

Warren Colburn, elected Member March 18, 1868, who died September 16, 1879.

Samuel J. Reeves, elected Member April 15, 1868, who died December 15, 1878.

Francis L. Vinton, elected Member August 5, 1868, who died October 6, 1879.

Norman A. Williams, elected Member February 17, 1869, who died October 12, 1879.

Franklin A. Stratton. elected Member May 3, 1876, who died July 17, 1879.

James E. Bell, elected Member March 5, 1879, who died June 8, 1879.

Charles A. Tasker, elected Junior November 4, 1874, who died October 4, 1879.

Thomas T. Tasker, Jr., elected Fellow January 7, 1873, who died August 19, 1877.

Memoirs of each are in preparation and will be published directly.

Respectfully submitted,

JOHN BOGART,
Secretary.

REPORTS OF COMMITTEES

PRESENTED AT THE ANNUAL MEETING, NOVEMBER 5TH, 1879.

ON METHODS OF NOMINATION FOR OFFICERS.

The following report was first presented at the Annual Meeting, November 6th, 1878. The Committee also at the Annual Meeting, November 5th, 1879, made a verbal report. It was then resolved that the Committee be continued, the report printed and issued to the Society for discussion and suggestion.

REPORT.

The Committee appointed at the regular meeting held during the Annual Convention, in June, 1878, to examine the methods of nominations for officers practiced by various societies and clubs, and to report a by-law embodying such features of the same as may seem best adapted to the use of this Society, respectfully report that they have performed the duty assigned them, and they present the following synopsis of the usages of ten associations, and also a plan proposed by a member of the Society. The existing by-law of the Society is appended for comparison.

The Institution of Civil Engineers, London:

17 Honorary Members, 1 148 Mombers, 1 200 Associate Members, 622 Associates.

President, 4 Vice-Presidents, and 12 members and 3 associates form the *Council.* (20 in all.)

Council elected annually.

President shall not serve more than 2 consecutive years, and then is not eligible for 3 years.

Senior Vice-President to be nominated for President unless he gives notice of intention to decline.

At the general meeting on the Tuesday before the Annual Meeting, the Council present a list of persons whom they nominate as suitable for offices. The list shall contain the names of 23 members and 6 associates.

The names presented (except for President and Vice-Presidents) shall be arranged alphabetically.

In voting this ballot, members may erase and substitute names, but the total number of names left must not exceed the number to be elected.

At the Annual meeting, the meeting chooses 2 scrutineers. The ballot is kept open for 1 hour.

The treasurer, secretary and other executive officers are appointed annually by the Council.

The Society of Engineers, London:

372 members.

The officers elected at the General Meeting in December.

The year of office begins on January 1st.

Council consists of—President, 3 Vice-Presidents, 8 members, 1 Honorary Secretary and Treasurer elected at the Annual Meeting. Also 6 Past Presidents who retire by seniority.

Members of Council are eligible for re-election.

The Council prepare a balloting list of proposed new Council and officers which shall be sent to each member *who has paid his subscription for the current year,* at least fourteen clear days before the date of the annual meeting.

Any member offering himself or proposing other members for election on the council must give in his or their names to the council on or before the first ordinary meeting in November. Such names shall be appended to the list proposed by council.

Members may erase and substitute.

At the annual meeting the President appoints 2 scrutineers.

In case of a tie, election to be decided by lot.

North of England Institute of Mining and Mechanical Engineers.

4 classes of members—Original. 750; ordinary, 17; associate, 12; honorary, 24; total, 803 members: students, 151.

Officers other than Secretary and Treasurer are elected from the original, ordinary and associate members, and consist of a President, six Vice-Presidents and eighteen Councillors, who with the Treasurer and Secretary constitute the council.

The President, Vice-Presidents and Councillors are elected at the Annual Meeting in August, and are eligible for re-election, with the exception of any President or Vice-President who shall have held office for three immediately preceding years, and such six councillors as may have attended the fewest council meetings during the past year.

The Treasurer and the Secretary are appointed by the Council and are removable by the Council subject to appeal to a general meeting.

Each member is at liberty to nominate in writing, and send to the Secretary not less than eight days prior to the ordinary general meeting in June, a list duly signed of members suitable to fill the offices—for the ensuing year.

The Council prepares a list of the persons so nominated, together with the names of the officers for the current year eligible for re-election, and of such other members as they may deem suitable. Such list must comprise at least 30 names. The list so prepared is submitted to the June meeting, and is the balloting list for August.

A copy of this list is posted to each member who may erase and substitute names, but names left must not exceed number to be elected.

The Chairman of the Annual Meeting appoints 4 scrutineers who receive the balloting papers, and after scrutiny destroy the same, and sign and hand to the Chairman a list of the elected officers.

Balloting papers may be sent by mail to Secretary or Chairman.

All Past Presidents are *ex-officio* members of Council, and Vice-Presidents who retire shall be *ex-officio* members for the following year.

Institution of Civil Engineers of Ireland.

148 members.

Officers: President, two Vice-Presidents, Honorary Secretary, and eight other members, who constitute the Council.

The President is not eligible for more than two years, and on vacating becomes an *ex-officio* member of Council. One Vice-President and two members of Council retire each year, but are re-eligible after one year.

Two members of Council are elected from the Associates. At the ordinary general meeting in December, the Council present a list of persons whom they nominate. Members may erase and substitute, leaving, however, twelve names. Lists containing more or less than twelve names to be rejected.

The meeting chooses two Scrutineers.

American Institute of Mining Engineers.

734 members.

Nominations may be sent in writing to the Secretary, accompanied with the names of the proposers, at any time not less than thirty days before the Annual Meeting, Two weeks before said meeting, the Secretary mails to every member the list of all nominations received. Voters may substitute, but the number of names voted shall not exceed number of officers to be elected.

At the Annual Meeting, three Scrutineers appointed by presiding officer.

Persons who have received the greatest number of votes are elected.

Union League Club, New York.

Annual Meeting held in January. Polls for election opened at 6:30 P. M., and open three hours.

At monthly meeting in December, a committee of seven, appointed by the Club at large, who shall report list of candidates.

Four inspectors and canvassers of election appointed by Club.

New York Club.

At Annual Meeting the Club ballots for officers. The presiding officer appoints three inpectors.

Candidates receiving the highest number of votes are elected.

Century Club of New York.

600 members.

The officers are chosen at each Annual Meeting by ballot. There are no provisions in the Constitution and By-Laws for nominations, or for inspectors of election.

Harvard College Plan.

Five Overseers elected each year.

A nominating committee of seven is elected by the electors at a public meeting. This committee makes up a list of twenty eligible persons and sends this to each voter. The voter fills out his ballot with six names, but is not confined to those suggested by the committee.

The ten names having the greatest number of votes are then submitted to the Annual Meeting as candidates. Each voter must erase five names, leaving five voted for.

The *nominations* are thus made by letter ballot, but the election is by personal ballot.

The New England Society, of Orange, N. J.

102 members.

Board of officers consists of a President, two Vice-Presidents, six Counsellors, a Secretary and Treasurer, elected annually. Elections conducted on the Hare System. At least one month before Annual Meeting, the Secretary must furnish each member with five blank forms for nominations. These ballots to be filled out and returned to Secretary within ten days, and opened as received and counted by a committee, of whom the Secretary shall be one. The committee's report to the Annual Meeting to be final.

E. Yardley's Plan.

Board of Direction to consist of eight. Nominating committee to present twelve names.

Members to erase or substitute. Each member to have eight votes which he may assign all to one man, or divide as he pleases. The eight names having largest number of votes to be elected. The Board then to choose from their own number President and Vice-Presidents.

The Board to elect Secretary and Treasurer not of their number, who shall hold office during good behavior or until election of successor.

Term of office to begin on January 1st following election.

American Society of Civil Engineers.

600 members.

Present By Law.

At the Annual Convention a nominating committee of five members, not officers of the Society, shall be appointed by the Convention. This committee shall present to the Board of Direction, on or before the first day of October, the names of the persons selected by them as candidates for officers. Of these, at least one Vice-President, three Directors, the Secretary and the Treasurer, shall be resident members. The Board of Direction shall thereupon cause such list to be posted in the rooms of the Society and shall issue at least twenty days before the Annual Meeting a letter ballot containing the names thus proposed.

Any five members, not officers of the Society, may present to the Board of Direction, on or before October 1st, a list of names proposed by them for officers, which list or lists shall also be issued for ballot.

No member of any nominating committee shall be presented by such committee as a candidate for office.

It will be seen that, in these eleven schemes of nomination, there are four distinct methods of selection.

I.—No previous nominations are provided for, but the election is supposed to be left to the discretion of members voting, as in the New York Club, the Century Club, and the New England Society of Orange. In practice, a nominating committee is appointed in the two first named organizations.

II.—The officers of the Society prepare a list of candidates, the number of the same being greater than the number to be elected, as in the Institution of Civil Engineers and the Institution of Civil Engineers of Ireland.

III.—Nominations are sent in by individual members, and a list of such, with additional names proposed by the officers, is sent out for ballot, as in the Society of Engineers (London), the North of England Institute of Mining and Mechanical Engineers, and the American Institute of Mining Engineers.

IV.—A nominating committee is elected by the members at a general meeting. which committee proposes a list of candidates to be voted for, as in the American Society of Civil Engineers, the Harvard College Board of Overseers, and the Union League Club. This feature is also retained in Mr. Yardley's plan.

The first method named was practiced by this Society previous to the annual meeting of 1877. The objection to it was that it placed the selection of officers entirely in the hands of the small proportion of members who attend the annual meeting, and the greater part of these being resident members, the Society at large had little voice in the election. A great deal of unnecessary time was consumed in the election, owing to the scattering nature of the vote. Usually several more ballots were taken than there were officers to be elected.

If efficiency and interest in Society affairs was the sole thing to be looked at in the selection of officers, the second plan would undoubtedly be the most effective, for the actual officers of the Society know best which of the members display an intelligent interest in its affairs. The plan is open, however, to the objection that it might tend to make the board a close corporation, and keep the same set in office all the time.

The third plan is open to serious objections in the case of this Society. Either members

will neglect to send nominations, leaving the board to make up the list, as in the second plan, or else a large number of nominations will be presented, most of them representing the personal preference of a single member. No judicious selection could be made from such a list by the mass of members who are widely scattered and who really know little about the business of the Society or the personal character of its officers.

The fourth plan appears to be the fairest and best, and when submitted to the Annual Convention in 1877 was approved by a unanimous vote. The few objections which have been made are to its mode of application. It has been urged that sufficient liberty of choice is not left to the members, and that, therefore, the plan is not as democratic as it should be. By the Harvard plan, the selection of candidates is certainly made in a more democratic manner, but involving as it does, practically, two ballots on the part of all the members, it is believed to be too cumbrous and unwieldy for the use of this Society. It must be borne in mind also that the offices of this Society are not merely honorary positions, but that the officers are the trustees of the property of the Society and the directors of its policy. By the law under which it is incorporated, a majority of the trustees constitute a quorum for the transaction of business, and they must, therefore, be so situated as to be able to attend the meetings of the board. The experiment of having a number of the trustees residents of remote districts, which was tried during the past year, has not been a success, as three members of the board have not attended a single meeting nor made any inquiries as to the action of their colleagues.

The committee, in deference to the opinion which is widely entertained, that more latitude should be given to the representation of the preferences of the members at large in the formation of the list for candidates, submit to the Society the subjoined by-law, as a substitute for that which was adopted at the Annual Convention in New Orleans in 1877.

Respectfully,

J. J. R. Croes,

Chairman.

November 6, 1878.

By-Law.

1. Before the annual convention each year, the Board of Direction shall make a territorial apportionment of the members of the Society (including also Associates and Juniors) into seven districts, each containing, as nearly as practicable, the same number of members, and shall present the same at the convention. The convention shall select a member from each of said districts to serve on the Nominating Committee. The Chairman of said committee shall be the member representing the district in which the place of business of the Society is situated.

2. Before the first day of August next ensuing, each member of said committee shall send to the Chairman a list of persons proposed by him for officers; giving one name for each officer to be elected. The Chairman shall thereupon send a full list of the names proposed to each member of the committee, who shall return said list to the Chairman, having first erased therefrom all names in excess of double the officers to be elected, except that only one name shall be left for President.

The Chairman shall prepare from the returned lists a balloting list, comprising the one name for President, three names for Vice-Presidents, the two names for Secretary, the two names for Treasurer, and the ten names for Directors which appear on the greatest number of lists.

The balloting list thus prepared shall be presented to the Board of Direction on or before the third Wednesday in September, and shall be sent by them to each member of the Society before the first day of October.

Each member entitled to vote at the annual election may erase any names on said list and substitute others, but no ballot shall contain, when presented to the Society, more than one name for each officer to be elected.

The ballots shall be received by the Secretary in accordance with the rules established by the Board of Direction for letter ballots, and all ballots received before twelve o'clock of the day of the annual meeting shall be placed in the hands of three tellers, appointed by the Presiding Officer, and by them canvassed, and the result certified to in writing and presented to the Chairman, who shall declare it to the Society. The person having the greatest number of votes for each office shall be declared elected. In case of a tie, the choice between the two candidates to be made by ballot of the members present.

No member of the Society who is in arrears for dues for either any previous or the current year, shall be eligible for office or for a position on the Nominating Committee.

On the Circulation of the Books of the Library.

The following report was presented by the Library Committee to the Board of Direction, adopted by the Board, submitted at the annual meeting, November 5th, 1879, and accepted :

To the Board of Direction of the American Society of Civil Engineers :

At the meeting of the Society held during the Annual Convention in Cleveland, on June 18th, the Library Committee was requested to report whether some plan may not be adopted to enable members living away from New York to consult the books of the library, under proper regulations to insure their return and to prevent injury.

The question here presented is by no means a new one to the members or officers of the Society, having been discussed at considerable length between July 2d, 1873, and 1st November, 1876. On the last named date the Board of Direction, in their Annual Report (Vol. 2. p. 146), said :

"The use of a library of the Society wil be restricted to resident members and those non-residents who occasionally visit New York, unless means be taken, under necessary restrictions, to send works to those who desire it, or here to make examinations for them. That by some such plan it is feasible to render a library of this character of great value to members remote from the centres of literary and professional knowledge, is believed, and full consideration of the matter by the Society, with a view to elaborate such a plan, is recommended."

This recommendation was not favorably considered by the annual meeting, and no action was taken upon it..

The reason for this indifference was, doubtless, that at the preceding annual convention, held in Philadelphia in June, 1876, the Committee on the Establishment of an Engineering Library and Museum, which was appointed in 1873, reported (Vol. 2, p. 82) that they had taken no action since the previous convention, and were discharged.

In addition, the Committee on the Policy of the Society, appointed in June, 1875, which made a careful and valuable report at the annual meeting in November, 1875 (Vol. 1, p. 318), had not in their report considered the possibility of such a dissemination of the library; while they had urged that the rooms should be kept open at all times to give members the opportunity to consult professional literature.

The committee above mentioned, on "Establishment of an Engineering Library," while suggesting the possibility of a circulating system, were not agreed as to its advisability. The Chairman, Mr. Leverich, said (Vol. 1, p. 226), "In these times of cheap and rapid expressage, duplicate volumes may be loaned to a non-resident member, and at small risk and cost sent to him, no matter how remote his residence is; while another member, Mr. C. Hermany, held that "this plan would not do, for the reason that nine out of every ten books sent out would never find their way back to the library" (p. 228).

Although the question of circulation of the library would thus seem to have been adversely decided, after much discussion, the Library Committee have felt it their duty to carefully consider it again in compliance with the desire of those of the older members who have forgotten the previous discussions, and the new members who are unacquainted with them, and earnestly hoping that some means might be devised to make the store of professional information in the library of the greatest possible value to all the members of the Society.

The conclusion the committee have reached is that it is impracticable and inexpedient to al ow volumes to be taken from the library, In support of this conclusion, they present the following considerations :

The functions and uses of a library for professional reference and study are as different from those of a library of general literature as are the contents of one from those of the other.

The library of the Society contains few books which can be read continuously within a limited time, with profit. The student of a particular subject for practical use in his profession requires generally not one book alone for perusal; and then, after the lapse of several days, another, to be in turn replaced by another, but he must have access to a quantity of works on the subject at one time, so that while the matter is fresh in his mind he may collate and compare a chapter, perhaps, of one, a sentence in another, a plate in a third, and a mere reference in others. Twenty or thirty books and papers may have to be consulted, and it is not infrequent to find among that number only one or two which give the exact information desired.

Mere titles and headings go for little in such a research. The particular treatment of

a subject, or the note sought cannot be surmised even from the name of the book.

One great practical objection to making a library of reference circulating is based on this fact. The matter treating of any subject of importance is scattered through so many books and technical journals, that in most cases a large number of volumes would have to be sent to the seeker for information, and possibly the greater portion of them would prove not to contain exactly what he needed. But he would be at the expense of their transportation, all the other members of the Society would be deprived of their use while they were absent, and the library would be at the risk of losing them, and consequently of the destruction of the value of the sets to which volumes belong.

The absence from the library of even a few volumes for several days, or more probably weeks, would be of more injury to the library itself and to the society by creating dissatisfaction than the inability of distant members to use the books.

It is probable that more real use of the library for study is made by non-resident members now than by residents. Members from a distance when visiting New York take advantage of that opportunity to look up the literature of the subject in which they are interested. If such a visitor found that the works he desired to consult were scattered to all parts of the country, to be absent for several weeks, he would unquestionably conclude that the library of the Society was a delusion, and the pretended facilities it offered a humbug.

The risk of losing the volumes sent out, is too great to be taken. The books most likely to be needed are not only valuable in themselves, but they have the additional value that rarity confers, and which is hardly to be estimated in money. No librarian or officer of the Society would feel warranted, even by the most liberal grant of authority by a Society vote, in either fixing a price to be deposited in advance for the loan of, for instance, one of the ten volumes of the papers of the Royal Engineers, or in sending without security one of them to Chicago or New Orleans.

The value of a book to its possessor is not to be estimated by any one else, and even with such a provision for exorbitant deposits as security, as to be prohibitory to the majority of the members, the loss or mutilation of valuable books would be certain. The testimony of librarians on this point is very strong, and offers a great mass of facts which are astonishing to those not familiar with the effects of bibliomania on otherwise respectable and honorable men.

The members entitled to the use of the library number now more than six hundred, and they are distributed over the whole area of the United States and Canada. The difficulties of enforcing any penalties for violation of rules or breach of confidence would be so great as to be practically insurmountable.

The conditions under which many of the books in the Library have been presented, make it impossible to allow them to be sent out. After deducting such books from the list, and also those which are rare and difficult to replace, and those which are in the character of encyclopædias and unfit for circulation, the number left for circulation would not be great, and their character would be such that they would not be likely to be in demand.

While the project of making the library a circulating one seems unadvisable, it is unquestionable that much may be done in the way of making it useful to all the members.

To this end, the first requisite is that members should know what may be found in the Library, and for this purpose a printed catalogue is essential, to be classified according to subjects. The card system of cataloguing is undoubtedly exceedingly useful and convenient for Library use, but to non-resident members it is valueless. For various reasons, mostly financial, no catalogue has yet been made, but the time has arrived when it is a necessity, and it should be the first duty of the Board of Direction to have it done. It is the only means by which members can be informed of the condition of the Library and of its needs. It is desirable that we should have a very full collection of American reports, and there are doubtless many in the possession of members who would send them to fill vacancies in our lists.

With a catalogue in its possession, supplemented by the monthly publication in the "Proceedings" of additions to the Library, a member could decide what he wanted to look at in advance of a visit, and thus save much of his own time and that of the Librarian.

The periodical literature of the day is so voluminous and so rich in valuable matter, that the Engineer cannot keep up with current advances in science without great cost and labor. It would be of immense advantage to members of the Society to have a topical index to the journals received by the Society published monthly in the Proceedings. The preparation of such an index would occupy the

whole time of one man, and he should be one familiar with several languages.

It would be out of the power of the Secretary to attend to this duty in addition to the business, the correspondence, the editorial work, and the necessary attention to members and others visiting the rooms of the Society.

With the aid of such an index, distant members could generally procure copies of the special articles they desired to see, at less expense than would be involved in correspondence and transportation of volumes from the Library.

It is a question to be carefully considered whether the expense of this work can be undertaken in the present state of the Society's affairs.

The matter of furnishing to members searches of authorities and abstracts or briefs on special subjects is worthy of consideration. Letters are sometimes received from distant members asking for such full and detailed information of this kind as could only be furnished after several days of carefu examination by an expert in the branch in quired about, and instances have occurred of much dissatisfaction being expressed, because all the information could not be given without expense. It may fairly be questioned whether this class of special research for individuals should be done at the expense of the Society. At the same time those who need the information are frequently not able or willing to bear the cost alone. For such cases there does not seem to be any relief except by the establishment of a fund the interest of which should be devoted to the purpose. The means of such establishment do not now appear. It is not advisable that the Society should go begging for money and thus lower its character and standing. The day may, and probably will, come, when the money will be offered.

The Committee invite a full and and frank discussion of these points and ask for practical suggestions from members of the Society,

MEMOIRS OF DECEASED MEMBERS.

SAMUEL J. REEVES,* Member A. S. C. E.

Died December 15th, 1878.

By the death of Mr. Reeves. American engineering has lost one who has contributed in no small degree to the extraordinary development of constructive iron work in America which the last twenty years have witnessed. While men markedly inferior in attainments, personal characteristics and influence have been noticed far and wide in the public prints, it is somewhat astonishing that the career of a man who has done so much practical good for his country as Mr. Reeves should pass away without exciting even a ripple of public comment, further than in the immediate professional and business circles with which he was in contact. The history of Mr. Reeves' life would be largely a history of iron making in America, an industry in which he was always in the van, impelled as much by the ambition created by a liberal education as by the purely vulgar considerations of trade.

Mr. Reeves was the son of David Reeves, and was born at Bridgeton, N. J., in 1818; was educated at Lawrenceville (N. J.) Academy, where he was prepared for Princeton College, from which institution he was graduated in 1837. To this educational preparation for his future career, Mr. Reeves added the experiences of travel, both in this country and in

*Committee to prepare memoir, John Griffen, Alfred P. Boller.

Europe. In 1846 he married a Baltimore lady, Miss Handy, who still survives him, together with five of the six children which were born to them.

Mr. Reeves commenced his business life about 1841 under his father and uncle, proprietors of the Cumberland Nail and Iron Works, at Bridgeton, N. J. The father and uncle were at the time, and had been for a long period also interested in a nail mill at Norristown and also in the Phœnix Iron Works, at Phœnixville, Pa., which latter was established in 1790 by Benjamin Longstreth. In 1827 the Phœnix Iron Works passed into the hands of Reeves, Whitaker & Co., afterwards (1846) Reeves, Buck & Co., which firm, in the same year, also became owners of the Bridgeton Works, with which the family connection, however, ceased in 1870. In 1855 the firm of Reeves, Buck & Co. became the Phœnix Iron Company, the title still retained. At Phœnixville the iron operations of the Reeves family were on a much larger scale than those conducted at Bridgeton or Norristown, where it was confined chiefly to the manufacture of nails. At Phœnixville the manufacture of railroad iron, pig iron and merchant bars was added to their nail production.

In 1846—November 16—the first rails were rolled at these works, since which time there has been a progressive increase in the iron shapes rolled at this establishment, until their "list" of shapes has become the most comprehensive of any rolling mill in America. In 1848 Reeves, Abbott & Co. erected a rolling mill and blast furnace at Safe Harbor, Penn., to roll rails for the Pennsylvania Railroad Company, of which enterprise Mr. Reeves was the virtual head. Mr. Reeves for many years and up to his death was a Director in the Board of the Cambria Iron Company, as his father before him had been. As President of the American Iron and Steel Association, a position filled by Mr. Reeves for ten years preceding his death, he had the unqualified support and confidence of its members.

From this brief summary, it will readily be seen that Mr. Reeves was necessarily an employer of labor on a vast scale, which, to successfully control and direct, required a talent for organization and system possessed by but few men. At the time of his death the great Phœnix Iron Works employed over 2,000 men in all its departments.

As might be expected in a Pennsylvanian and an iron master, Mr. Reeves was a strong Protectionist of the Carey school, and he was ever ready to defend the principles of that school of political economy with an earnestness bred of conviction and a thoroughness due to thoughtful study. Mr. Reeves by nature was extremely conservative, and had he been simply the self made man, self taught, with only the experience of his local surroundings, would have been a successful follower in the improvements continually introduced into the manufacture of iron, instead of being in the van. He would have made rails, and good ones, too, all his life, and been successful as a business man. Fortunately,

the advantages of a liberal education and the opportunities of travel tempered his natural disposition and broadened his views, so that, as always comes to a naturally strong man, with a trained intellect, he was ambitious to accomplish something more than the mere success of making money.

Seconded by the able assistants he called around him, he, as rapidly as he was able and so soon as he saw an opening for new ideas, introduced the manufacture of specialties at Phœnixville, and in every sense was the pioneer of constructive wrought iron work in America. The double lipped wrought iron railroad chair was first made at Phœnixville by rolling, enormous quantities of which were used on our railroads until the pear head section of rail gave way to the now universally adopted girder section with a straight stem.

While it is true the Trenton Works made the first rolled beam in this country (9 inch in 1853), the Phœnix Works were practically the first to manufacture for the market beams of varying sizes and sections, for many years being without a competitor—until 1864 they were the only manufacturers of large beams and channels in America. One of the boldest strides forward was the manufacture of hydraulic die forged eye bars, undertaken with a view to supplying such bars for the channel span of the Steubenville bridge about being constructed by Mr. Linville in 1863.—the first of the great spans with which we have since become so familiar.

Foreseeing with an almost prophetic eye the great demand that would spring up for constructive iron work, Mr. Reeves made all his improvements tend towards the manufacture of "shapes," and the designing and construction of all descriptions of wrought iron framing. In 1862 the wrought iron column known as the "Phœnix Column" was patented by Mr. Reeves, and for a long time it was considered almost impossible to build a long span bridge without its use. This patent was contested on the ground of infringement by Linville & Piper, in 1867, but was sustained by the judge on its priority and principles. Previous to the panic of '73 Mr. Reeves commenced the "new mill" at Phœnixville, on a scale second to none in America, being 930 feet long and 430 feet wide. At the time of the panic it was almost completed, and still awaits the revival in the iron trade that will warrant the additional product that such a mill is capable of turning out. It was intended that this mill should be perfect in every proved modern appliance for manufacturing iron and steel, and no labor or money was spared to carry out this view.

It will be seen from the above rapid summary of the development of the Phœnix Works, of which Mr. Reeves was practically the sole head, that American engineering owes much to him, and the Transactions of the American Society of Civil Engineers form a fitting tablet to place this debt on record. But far above all is the legacy of character Mr. Reeves has left his family and friends, and the example of a wonder-

fully successful business career, untainted by trickery or any dishonorable dealing.

Mr. Reeves was not perfect; he had his peculiarities of character and imperfections of humanity like others; he had his enemies, like every other strong man; but his heart was warm, his aspirations high, and an irreproachable integrity was his through life. He was a gentleman in the highest and best sense of the term, generous and sympathetic, and whose death is a real bereavement to those with whom he was associated.

FRANKLIN ASA STRATTON,* Member A. S. C. E.

Died July 17th, 1879.

Franklin Asa Stratton was born in Northfield, Mass., November 30, 1829. His parents were Asa and Sophia Stratton, the latter still living.

Early manifesting a fondness for books and study, he was allowed to gratify his own childish wish of attending school at the age of three and a half years. After finishing the common school course he entered the academy of his native town. He exhibited an aptitude and decided taste for mathematics, taking up and completing, unassisted, the study of algebra, that branch not being included in the school course.

He was remarkable, even in those early years, as a patient and indefatigable student, not only of text books, but those embracing a wide and varied range of knowledge, and for his perfect self-reliance. These qualities gave him high rank in the boys' school at Brattleboro, Vt., which he entered, after completing his academic course, and which was under the charge of the Rev. Addison Browne, who taught the classics and higher mathematics, including civil engineering. He here excelled in mathematics, and mastered the difficulties of problems which had puzzled many teachers.

On leaving the school at Brattleboro, Vt., he formed a party of engineers at Rochester, N. Y., and as a mark of confidence in his ability he was entrusted with the construction of a short road to Lake Ontario, which he completed to entire satisfaction. As a well-deserved tribute to the perfect confidence placed in his judgment and discretion, it should be recorded that the work here included not only the engineering and building of the road, but the disbursing of the moneys invested in the enterprise, and this at the early age of twenty years.

From here he went to the Toledo & Wabash Railroad, and was located at Lafayette, Ind., until the completion of the road. Leaving Lafayette he went to Fort Dodge, Iowa, where he opened a land office, transacting the business connected with that position.

At the time of the massacre at Spirit Lake in 1857, he commanded a company of riflemen in a severe mid-winter campaign against the Sioux

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* Committee to prepare memoir, F. C. Prindle.

Indians. At the outbreak of the Rebellion he was engaged in the study of law, but heeding his country's call and need, he formed a company, went to Washington and entered the military service as captain of Company A, Eleventh Pennsylvania Cavalry, and was regularly promoted, to the grade of major in September, 1862, Lieut.-Colonel, September, 1864, Colonel, May, 1865, and Brevet Brigadier General in September, 1866.

Of Gen. Stratton's military service, "Bates' Martial Deeds of Pennsylvania" makes honorable mention in a biographical notice.

We find that he was engaged in nearly thirty pitched battles, beside many skirmishes and minor affairs. He was twice wounded, viz., on the 17th of March, 1863, in a sabre charge at Franklin, in which he displayed great courage and skill; and again in a hand to hand encounter in the battle of October 7th, 1864, where he received a sabre cut in the hand.

He particularly distinguished himself in the raid led by Wilson and Kautz, five hundred miles inside of the enemy's lines, in which three battles were fought and thirty miles of the Danville Railroad were destroyed, he having the lead in withdrawing in face of vastly superior numbers sent to intercept them.

In the last campaign against Lee, his command had the honor of opening the final battle of the war in Virginia, it having occupied with Gen. Miles' division of infantry the famous Lynchburg turnpike, leading out of Appomattox.

In addition to constant service in the saddle, he performed a great deal of military engineering for the government, making military maps of the country before Petersburg, for Gen. Mansfield, which were of great service during the latter part of the war.

Gen. Stratton was married February 24, 1866, to Mrs. Georgie E. Griffith, *née* Keeling, of Norfolk, Va., who still survives him, and on the 28th March, 1867, was commissioned a Civil Engineer in the naval service, and ordered to duty as Civil Engineer of the Washington Navy Yard, a position formerly filled by Gens. Rosecrans, Benham and others of the United States Engineer Corps. July 9, 1875, he was ordered to League Island in charge of the construction of the important public works projected for a navy yard at that point, and where he was stationed at the time of his death.

In addition to these arduous duties, he served as a member of the Boards of Civil Engineers appointed by the Navy Department to examine the sites of the League Island, Mare Island, and New London Navy Yards, and prepare plans for their development and permanent improvement upon a large scale, and was also entrusted with other important professional duties by the government, all of which were performed with zeal and efficiency.

While engaged at League Island a severe storm visited that vicinity, in October, 1878, which culminated in a disastrous flood, causing an

overflow of the dykes and blowing down the shiphouse, etc. During this crisis Gen. Stratton remained at his post of duty almost constantly for several successive days and nights, personally directing repairs and trying to avert further disaster, and animating his men in the hurried and imperative work of saving government property, utterly regardless of personal discomfort and exposure, being often knee deep in mud and water and thoroughly drenched. A severe and deep seated cold was contracted as a result of this exposure, which culminated in an attack of typhoid pneumonia, from which he died, at Chestnut Hill, near Philadelphia, on Thursday evening, July 17th, 1879, in the fiftieth year of his age,

Gen. Stratton was remarkably modest and retiring in his character, which also possessed that most rare, difficult and victorious element, a patient spirit—one that could learn to labor and to wait and abide its time. Professionally he possessed superior abilities as a civil and mechanical engineer, and in his death the government has lost a faithful and efficient officer; the profession, a valued member, whose attainments and experience, combined with his personal worth and estimable character, furnish an example worthy of all notice; and his personal acquaintances, a warm and generous friend.

His whole life was full of work--hard work, both mentally and physically, and it deserves to be written as a golden honor to his memory, that during all these busy years of varied and arduous service, away from his home, his love and continual remembrance of his aged mother was a noticeable feature of his excellent character.

Reviewing the character of Gen. Stratton, we find it strikingly illustrative of the trite but truthful adage, "the boy is father of the man;" from the early schooldays, until the close of his laborious and eventful life, we see the same masterful spirit modestly asserting itself, persistently surmounting difficulties and bravely ignoring self in the discharge of his duties, until the loyal soldier, the faithful servant, the true friend, and the loving husband, father, and son falls at his post—with the harness on—to be sincerely mourned by all who knew him.

JAMES E. BELL,* Member A. S. C. E.

Died June 9th, 1879.

James E. Bell was born in Cincinnati, Ohio, on the 28th of December, 1849. His grandfather was a captain in the British army, who came to America in 1812, just before the declaration of war. He first settled in Lancaster, Pennsylvania; but in 1817 he removed to Cincinnati, and, with the exception of a few years' residence at Rising Sun, Indiana, he continued to be a citizen of Cincinnati until his death.

* Committee to prepare memoir, Col. Wm. E. Merrill.

Mr. Bell's father, Joseph Bell, Esq., has long resided in Cincinnati, where he is in charge of an extensive foundry and machine shop.

James E. Bell received his early education in the common schools of Cincinnati, and finished his course at the Woodward High School in June, 1869. In September of that year he entered the Rensselaer Polytechnic School at Troy, N. Y., whence he was graduated in June, 1873. He was thus careful to prepare himself by special study in the best schools, and did not assume the title of "engineer" until his diploma gave him the right to use it. The success which at the time of his early death had already attended his efforts in his chosen profession was largely due to his excellent training, by means of which he was soon able to erect a stable edifice of practice on a broad foundation of the fundamental principles of mechanics and engineering.

Ambitious to excel, and desirous of speedily acquiring experience in practical construction, he sought and obtained service, during his vacations, as an assistant to Jno. C. Wilson, C. E., engineer in charge of the erection of the Newport and Cincinnati Railroad Bridge over the Ohio river.

After leaving Troy Mr. Bell was employed about three months on surveys connected with the location of the Cincinnati Southern Railway, under the direction of the Chief Engineer, Mr. Wm. A. Gunn (Member Am. Soc. C. E.). For nearly a year longer he had charge of a party engaged between Dayton and Springfield, Ohio, in re-surveying a route for the C. C. C. and I. R. R. (Dayton Short Line or Bee Line).

In July, 1874, he took service under Col. W. E. Merrill, U. S. Engineers (Member Am. Soc. C. E.), and made a survey of the Big Sandy river from its mouth to Warfield, Ky., on the Tug Fork, and to Piketon, Ky., on the Louisa Fork. In 1875, in obedience to an Act of Congress, this survey was extended up the Louisa Fork to the mouth of Dismal Creek, in Virginia. This second survey was also made by Mr. Bell.

In November, 1875, he was assigned to duty at Hoard's Rocks, W. Va., on the Monongahela, below Morgantown, with orders to continue the work of building a masonry lock and dam at that point. He remained on this duty until November, 1876, when all work was stopped, owing to the exhaustion of the appropriation.

In June, 1877, Mr. Bell was put in charge of the improvement of the Little Kanawha river, and he remained on this duty until work was stopped by cold weather. This was his last service under the government. His reports on the Big Sandy, and his reports of operations on the Monongahela and on the Little Kanawha, will be found in full in the Annual Reports of the Chief of Engineers.

On the 10th of July, 1878, he received from the Board of Public Works of the City of Cincinnati the appointment of Superintendent of the City Water Works. He filled this important and responsible position with great acceptance until his death on the 9th of June, 1879, at the

early age of twenty-nine. He succumbed to an attack of inflammation of the bowels. He left a widow, but no children; having been married but little more than a year.

He was elected a member of the American Society of Civil Engineers on the 5th of March of the present year, and thus was numbered amongst us for the very brief period of three months.

Of a genial disposition, his business relations were always pleasant; but his kindness of heart never caused a relaxation of official vigilance. Sternly honest himself, and animated by a keen sense of duty, shirking contractors found no weak spots that would excuse them from a complete and exact performance of their engagements. Full of zeal for his profession, with the best available training and an increasing experience, and already the incumbent of one of the highest professional positions in his native City, life seemed to present for his acceptance the highest honors of his chosen career. But the destroyer seized the strong man in the vigor of his youth, and in a few short days his honors had faded, his place had been filled by another and his memory alone was left to the friends that loved him and had rejoiced in his early success.

ADDITIONS TO

LIBRARY AND MUSEUM.

Donations to the Library.—Members and others are asked to contribute regularly to the library of the Society, copies of government, municipal, railway, canal and other reports, specifications, profiles, maps, photographs and like matter, making up the record of engineering operations for the past or present, and to inform the Secretary where such may be had. Duplicate copies are desired, for transmission to foreign societies in return for works collected and sent to this library by them; also for exchange with members and others who wish complete sets referring to particular subjects. Donations of old or new reports or pamphlets which refer to or illustrate Engineering constructions or operations are particularly solicited. Many of these may be really of great importance as a part of the Library, and as possibly containing information which might not otherwise be preserved.

"Copies for distribution" named in this list will be sent to members forwarding stamps to prepay postage until the supply is exhausted.

From Administration des Ponts et Chaussées, Paris:

Annales, September, 1879.

From Aeronautical Society of Great Britain, Fred. W. Brearey, Hon. Secretary, London:

Thirteenth Annual Report of the Society. 1878.

From American Chemical Society, P. Cassamajor, Secretary, New York:

Journal of the Society. Vol. I., Nos. 8 and 9.

From American Institute of Mining Engineers, Dr. Thomas M. Drown, Secretary, Easton, Pa.:

Proceedings of the Meeting held at Montreal, September, 1879.

A direct Process of Copper Smelting. H. M. Howe.

Experiments with Charcoal, Coke, and Anthracite in the Pine Grove Furnace, Pa. John Birkinbine.

Recent Improvements in Concentration and Amalgamation. John A. Church.

An Autographic Transmitting Dynamometer. Wm. Kent.

The Hygiene of Mines. R. W. Raymond.

Washing Phosphoric Pig Iron for the Open Hearth and Puddling Processes at Krupp's Works, Essen. A. L. Holley, L.L.D.

Relations of Sulphur in Coal and Coke. Dr. J. P. Kimball.

Notes on the Zinc Deposits of Southern Missouri. A. W. Raymond.

From Argentine Scientific Society, Don Edwardo Aguirre, Secretary, Buenos Ayres:

Annals of the Society. September, 1879.

From Boston Public Library, Mellen Chamberlain, Librarian, Boston:
Bulletin of the Library. October, 1879.

From E. S. Chesbrough, Chicago:
Third Annual Report of the Department of Public Works of the City of Chicago.

From Francis Collingwood, New York;
Photograph view of Trestle for the erection of Second Block of the New York Approach of the East River Bridge, together with the Arch over Cliff street.
Photograph view of New York Anchorage and first two Arches of the Approach of East River Bridge.

From Commissioners of Second Geological Survey of Pennsylvania, Wm. A. Ingham, Secretary, Philadelphia:
Part First. The Northern Townships of Butler Co.
Part Second. A special Survey made in 1875 along the Beaver and Chenango Rivers in Beaver, Lawrence and Mercer Counties. H. Martyn Chance.
Second Report of Progress in the Laboratory of the Survey at Harrisburg. Andrew S. McCreath.

From Charles E. Emery, New York:
United States Centennial Commission. Reports and Awards Group XX. Motors, Hydraulics and Pneumatic Apparatus, &c. Francis A. Walker.

From John Ericsson, New York:
Contributions to the Centennial Exhibition. Capt. John Ericsson.

From Albert Fink, New York;
Proceedings of Meetings and Conventions of Officers of Eastern and Western Railroads held in June and December, 1878; January, April, May, June and September, 1879.

From Julius E. Hilgard, Assistant in Charge, United States Coast Survey, Washington, D. C.:
Methods and Results; Secular Change of Magnetic Declination in the United States and at some foreign stations. 3d edition. (Copies for distribution.)

From John W. Hill, Cincinnati:
Report of the Board of Experts on the Test Trial of the Warden Compound Pumping Engine at the Hunt Street Station to the Board of City Commissioners of Cincinnati, Ohio, 1879. (Copies for distribution.)

From Hungarian Society of Engineers and Architects, Budapest:
Transactions, January to July inclusive, and October, 1879.

From Institution of Civil Engineers, James Forrest, Secretary. London:
Excerpt from Minutes of Proceedings. Edited by James Forrest. Note on a Graphic mode of ascertaining the Flow of a Mill Stream. Wm. Shelford.

From Institution of Engineers and Ship builders, W. J. Millar, Secretary, Glasgow, Scotland:
Transactions of the Institute. Vol. XXII.

From E. D. Leavitt, Jr., Cambridgeport, Mass.:
City of Boston; Improved Sewerage; Pumping Engines.

From Hon. F. W. Lincoln, Boston:
The History of the Bunker Hill Monumental Association during the first century of the United States of America. George Washington Warren. Boston, 1877.
Proceedings of the Bunker Hill Monumental Association at the Fifty-sixth Annual Meeting, June 17th, 1879. With Address of Frederick W. Lincoln.

From Thomas J. Long, New York:
Annual Report Department of Docks of New York, made of the year ending April 30th, 1877.

From E. P, Lull, Commaner U. S. N., Washington, D. C.:
Reports of Explorations and Surveys for the location of Interoceanic Ship Canals through the Isthmus of Panama and by the Valley of the River Napipi, by U.S. Naval Expeditions, 1875. Commander E. P. Lull, U. S. N., and Lieut. Frederick Collins, U. S. N. Washington, 1870.

From New York Meteorological Observatory, Department Public Parks, Daniel Draper, Director, Central Park, New York:
Abstracts of Registers from Self-recording Instruments, September and October, 1879.

From North of England Institute Mining and Mechanical Engineers, Theo. Wood Bunning, Secretary, Newcastle-on-Tyne, England:
Transactions, February, March, April, May, June, August, 1876; May and June, 1878; August, 1879.

From Mechanics' Institute, S. H. Wheeler, Cor. Secretary, San Francisco, Cal.:
Reports of the Eleventh, Twelfth and Thirteenth Industrial Exhibition under the auspices of the Mechanics Institute of San Francisco.

From Midland Institute of Mining, Civil and Mechanical Engineers, Joseph Mitchell, Secretary, Barnsley, England:
Transactions, Vol. VII. Part XLVII. August and September, 1879.

From Charles Paine, Gen. Sup't. L. S. and M. S. R. R., Cleveland, Ohio:
Memorandum of Tests showing relative cost of burning oil (with Campbell's Patent Oil Burner) and coal; for Fuel in Stationary Engines at Cleveland Engine shops, Sept. 24th and 25th, 1879.

From H. V. and H. W. Poor, New York:
Manual of the Railroads of the United States for 1878–79.

From the Publishers Revue Générale des Chemins de fer. Edgar Monjean, Secretary, Paris:
Revue Générale des Chemins de fer. July and August, 1879.

From the Royal United Service Institution, Capt. B. Burgess, Secretary, London:
Vol. XXIII. No. 101. Double Number. Journal of the Institution.

From the Saxonian Society of Engineers and Architects, Dr. Kahl, Secretary, Dresden:
Transactions. Part 1, 1858, containing description of Viaduct between Waldheim and Limmritz. Part 1, 1879.
Photograph and detail Drawings of Viaduct in Zschopauthale between Waldheim and Limmritz.

From Société des Ingenieurs Civils, M. Mallet, Secretary, Paris:
Memoires de la Société. July and August, 1879.

From Society of Gas Lighting, George W. Dresser, Secretary, New York:

The Waste of Energy in the production of Water Gas. Eugene Vanderpool. (2 copies.)

From D. Torrey, New York:

A sample of Iron clad Steel Wire.

From J. Nelson Tubbs, Rochester, N. Y.:

Annual report of Executive Board in charge of Water Works, Fire and Highway Departments and Street Improvements of the City of Rochester for 1878.

From United States Centennial Commission, Philadelphia, Pa.:

Report of the Director-General of the Centennial Exhibition, Philadelphia, 1876, including Reports of Bureaus of Administration. Vols. I and II.

Reports of the President. Secretary and Executive Committee, together with the Journal of the final session of the U. S. Centennial Commission. Philadelphia, 1876.

Appendix to the reports of the U. S. Centennial Commission and Centennial Board of Finance.

Grounds and Buildings of the Centennial Exhibition Edited by Dorsey Gardner.

Six volumes, containing Reports and Awards of Groups 1 to 36. and Group on National, State and other Collective Exhibits.

From United States Light House Board, Washington, D. C.:

List of Towers, Beacons, Buoys, Stakes, Spindles and other Day Marks in the Third Light House District. 2 copies.

List of Beacons, Buoys, Stakes and other Day Marks in the Fifth Light House District. Corrected to October 1, 1879. 2 copies.

List of Towers, Beacons, Buoys, Stakes and other Day Marks in the Sixth Light House District. Correcied to November 1. 1879. 2 copies.

From Samuel Webber, Manchester, N H :

Manual of Power for Machinery, Shafts and Belts, with the History of Cotton Manufacture of the United States. Samuel Webber. New York. 1879.

From other sources:

The Library Journal, Vol. IV, Nos. 4, 5, 7, 8, 9 and 10.

Annual Report of the State Engineer and Surveyor on the Canals of the State of New York for 1878. H. Seymour, Jr.

Special Report on the Coal fields of Little Sequatchee, with a general description of the Cumberland Table Land. J. B. Killebrew, Nashville, Tenn. 1876.

Exploration of the Colorado River of the West and its tributaries. Explored in 1869 1870, 1871 and 1872,

Key to the Geology of the Globe. Richard Owen, Nashville, Tenn. 1857.

Report on the Geology of the eastern portion of the Uinta Mountains. J. W. Powell.

Mineral and Agricultural Resources of the northern portion of Tennessee, along the Cincinnati Southern and Knoxville & Ohio Railroads. J. B. Killebrew. Nashville, Tenn. 1876.

The Mineral Wealth, Climate and Rainfall and Natural Resources of the Black Hills of Dakota. W. P. Jenney, Washington 1876.

Report on the Ocoee and Hiwassee Mineral District. J. B. Killebrew, Nashville, Tenn. 1876.

The Delta of the Mississippi. C. G. Forshey, Cambridge. Mass. 1873.

History of the Discovery and Settlement of the Valley of the Mississippi. Vols. I and II. John W. Monette, New York. 1846.

Annual Report upon the Improvement of the Mississippi River. Appendices to Annual Report of Chief of Engineers for 1875, 1876 and 1877. Maj. C W. Howell.

Annual Report upon the Improvement of the South Pass of the Mississippi River, June 30. 1878. Capt. M. R. Brown.

Ninth Report upon the Improvement of the South Pass of the Mississippi River. April 15, 1878. Capt. M. R. Brown.

The Physics of the Gulf of Mexico and of its chief affluent, the Mississippi River. C. G. Forshey. Salem, Mass. 1878.

Lists of Elevations, principally in that portion of the United States west of the Mississippi River. Henry Gannett. Washington. 1877.

Commercial Freedom for the Mississippi Valley. Capt, John Cowdon. Memphis, Tenn. 1877.

The World's Navigatlon. The Problem of River Mouths. W. T. Stackpole. Bloomington, Ill. 1879.

Fresh-Water Shell Mounds of the St. John's River, Florida. Jeffries Wyman. Salem, Mass. 1875.

Tobacco; Its Cultnre in Tennessee, with statistics of its commercial importance, etc. J. B. Killebrew. Nashville, Tenn. 1876.

Bulletin of the United States Entomological Commission. No. 2. F. V. Hayden. 1877.

Bulletin of the United States Geological and Geographical Survey of the Territories. Vol. II., No. 4. Vol. III., Nos, 1 and 2. F. V. Hayden. 1877.

The Winds of the Globe; or, The Laws of Atmospheric Circulation over the surface of the Earth. James H. Coffin. Washington. 1875.

ANNOUNCEMENTS.

The meetings of the Society during December will be on the 3d and 17th. The paper by A. G. Menocal, on Interoceanic Canal Projects, published in the present number of the Transactions (November, 1879) will be discussed at both meetings.

On the evening of the Annual Meeting, on the 5th of this month, a reception and supper took the place of the formal dinner heretofore given on similar occasions. Those present enjoyed a very pleasant evening, and it is understood, approved the change.

MEMBERS OF THE SOCIETY are requested to contribute papers on Engineering subjects, giving results of practice, or discussing pertinent theoretical questions; their comments upon papers published in Transactions are solicited, and they are urged to contribute from note-books and other records whatever may bear upon the subjects considered, or upon other practical topics. A list of subjects relating to the practice of engineering and its connection with kindred art and public affairs, on which papers are desired, may be found on page 60, Vol. V.

ILLUSTRATIONS OF PAPERS presented for publication should be distinctly drawn, in *broad, sharp lines*, upon *white, smooth* (not "egg" or enameled) paper, with perfectly (not glossy, or gray) *black* ink, to a scale twice or thrice greater than the print is to be, which in no case should require folding in more than one direction (*i. e.*, the depth of plate, as inserted in Transactions, should not exceed 7 inches). Shades are to be produced by variations in size and spacing of *black* lines; no brush work or colors are admissible. Unless figures and letters can be *well* put in, simply pencil them, leaving the engraver to insert them on the plate. Always put a lineal scale upon each drawing.

IN TRANSMITTING LETTER BALLOTS members of the Society are requested to conform in all respects with the printed regulations issued with the ballots. These regulations are frequently not complied with. Ballots are received without the signature of the member on the outer envelope, with initials instead of full signature, or with other irregularities. When laid before the Society such irregular ballots are thrown out, and members sending them lose their votes. The regulations seem to be as simple as possible to secure a fair secret ballot.

Members who desire to secure complete sets of the Transactions of the Society are requested to send to the Secretary a list of the papers which are needed to fill their sets. Some of the earlier papers are out of print. If orders are received for a sufficient number to warrant the expense, a reprint will be made.

The following resolution was adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications:

Whereas, the metric system of weights and measures is now extensively used abroad, and whereas it is desirable that the relation of the units of differing systems be made familiar to all by comparison:

Resolved, That members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimensions by the metric system, in connection with those of the system in general use.

The House of the Society is at 104 East Twentieth street, one door east from Fourth avenue, and near the southwest corner of Gramercy Park. It is open from nine o'clock A. M. to five o'clock P. M. each business day, except Saturday, when it is closed at three o'clock P. M.

The Library and Conversation Rooms will also, for the present, be open every *Thursday evening*, from 7½ to 10 P. M. Members are invited to avail themselves of the opportunities afforded on Thursday evenings, both for consultation of books and periodicals and for conversation.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

		Date of Election.
BONTECOU, DANIEL	466 West Twenty-third street, New York City, N. Y.	November 5, 1879.
DEMPSTER, ALEXANDER	City Engineer, Pittsburg, Pa.	" " "
RENO, JAMES H.	County Engineer, Court House, Pittsburg, Pa.	" " "

CHANGES AND CORRECTIONS.

MEMBERS.

HAVEN, WILLIAM A. ..... Engineer in charge construction Buffalo Division N. Y. L. E. & W. R. R., Buffalo, N. Y.

MCCOMB, DAVID E. ..... P. O. Box 289, Washington, D. C.

MONROE, J. ALBERT ..... Mississippi River Commission, 1351 Washington avenue, St. Louis, Mo.

NICOLLS, WILLIAM J. ..... Engineer Long Island Railroad, Jamaica, Queens Co., N. Y.

PARKHURST, HENRY W. ..... Chief Assistant Engineer, Plattsmouth Bridge, Plattsmouth, Nebraska.

SCHMIDT, MAX E. ..... Care of U. S. Engineers, Memphis, Tenn.

SHINN, WILLIAM P ..... Vice President and General Manager Vulcan Iron Works, 221 Oliver street, St. Louis, Mo.

STANLEY, IRA N ..... 88 Van Dyke street, Brooklyn, N. Y.

WHITFORD, OSCAR F. ..... East Plattsmouth, Iowa.

ASSOCIATE.

DU BARRY, EDMUND L. ..... 621 Penn. Avenue, Washington, D. C.

JUNIORS.

EMONTS, WILLIAM A. G. ..... San José, Costa Rica, *via* Panama.

HORTON, SANFORD ..... Engineer Department N. M. & S. P. R. R., Las Vegas, New Mexico.

ILLSLEY, WILLIAM A. ..... P. O. Box 2353, Leadville, Colorado.

KENNEDY, JAMES C. ..... P. O. Drawer 33, Owen Sound, Ontario, Canada.

STAHLBERG, ALBERT J. ..... South Pacific Coast Railroad, foot of Market street, San Francisco, Cal.

WHINERY, SAMUEL ..... Assistant Engineer Elk River Shoals, Wheeler Station, Lawrence Co., Alabama.

RESIGNATION.

SCHUYLER, JOHN ..... October 18, 1879.

DEATH.

WILLIAMS, NORMAN A. ..... Elected Member February 17, 1869. Died October 12th, 1879.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. V.—December, 1879.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

NOVEMBER 19TH, 1879.—The Society met at 8 P. M., President A. Fink in the chair. A paper, entitled "Inter-Oceanic Canal Projects," by A. G. Menocal, Member Am. Soc. C. E., was read by the author and discussed by Messrs. Chanute, T. C. Clarke, Cooper, Emery, Fink, Ford, and Menocal.

DECEMBER 3D, 1879.—The Society met at 8 P. M., Vice-President Chanute in the chair. The awards of the Norman Medal and Book Prize for the past year were then announced as follows:

The Norman Medal to EDWARD P. NORTH, Member Am. Soc. C. E., for the paper, "*The Construction and Maintenance of Roads*," published in Transactions, Vol. VIII., No. CLXXX. (May, 1879).

The Norman Prize of Books to MAX E. SCHMIDT, Member Am. Soc. C. E., for the paper, "*The South Pass Jetties*," published in Transactions, Vol. VIII., No. CLXXXIII. (August, 1879).

Ballots for admission to membership were canvassed, and the following were declared elected as Members: Edward Canfield, of Buffalo, N. Y.; Henrique Harris, of Brooklyn, N. Y.; Thomas McKeown, of Hamilton, Ont., Canada; Charles L. Strobel, of Pittsburgh, Pa. Elected as Associate: L. M. Lawson, New York, N. Y.

The discussion on the subject of Inter-Oceanic Canal Projects was resumed and continued by Messrs. J. C. Campbell, Chanute, Emery, F. M. Kelley, Macdonald, Menocal, North, W. H. Paine, Shelborne and Worthen.

DECEMBER 17TH, 1879.—The Society met at 8 P. M., Vice-President Chanute in the chair. The discussion on the subject of Interoceanic Canal Projects was resumed. Papers were presented, through the Secretary, by Messrs. Evans, F. M. Kelley, M. E. Schmidt and C. A. Sweet, and the discussion was continued by Messrs. Long, Menocal, Appleton, Shelbourne, S. Stevens, and Peter Cooper.

OF THE BOARD OF DIRECTION.

October 31st, 1879.—Applications for membership were considered. The Annual Report was perfected.

November 11th, 1879.—The following committees were appointed: On Finance—William H. Paine, C. Vandervoort Smith, G. K. Warren. On Library—J. J. R. Croes, E. B. Van Winkle, O. Chanute.

Applications for membership were considered. The issue of a circular was authorized in reference to a record of members desiring engagements. Action was taken as to members in arrears for dues.

December 5th, 1879.—Applications for membership were considered. The Secretary was directed to issue copies of forms for applications, with a circular. Appropriations were made.

REPORT OF THE TREASURER

For the Year Ending November 5th, 1879.

Presented and Accepted at the Twenty-seventh Annual Meeting.

Receipts.

Balance on hand November 6th, 1878		$749 51
Entrance fees		800 00
Fellowship subscription,		150 00
Current dues—from 82 Resident Members	$2 000 00	
Do. from 214 Non-resident Members	3 062 50	
Do. from 3 Resident Associates	45 00	
Do. from 8 Non-resident Associates	75 00	
Do. from 7 Resident Juniors	82 50	
Do. from 34 Non-resident Juniors	340 00	
		5 605 00
Past dues—from 11 Resident Members	$350 00	
Do. from 37 Non-resident Members	725 00	
Do. from 1 Resident Associate	30 00	
Do. from 1 Non-resident Associate	30 00	
Do. from 4 Non-resident Juniors	40 12	
		1 175 12

Dues for year beginning Nov. 5th, 1879:		
From 22 Resident Members	$550 00	
From 83 Non-resident Members	1 245 29	
From 1 Resident Associate	7 00	
From 3 Non-resident Associates	30 00	
From 1 Resident Junior	15 00	
From 12 Non-resident Juniors	120 00	
		$1 967 29
Sales of Publications		566 28
Certificates of Membership		49 00
Advertisements		503 65
From former Secretary—Balance		65 00
Miscellaneous		29 00
Interest on Fellowship Fund Bonds	$560 00	
Interest on Norman Medal Fund	70 00	
Interest on Savings Bank Deposit	40 31	
Interest on Railroad Stock	82 80	
		753 11
		$12 412 96

DISBURSEMENTS.

Rent	$1 600 00
Janitor, House Supplies, Fuel, Furniture, Water and Gas	981 23
Library	154 48
Publications	4 406 71
Insurance	34 23
Postage	545 24
Salaries	3 000 00
Stationery and Printing	502 91
Annual Meeting and Convention	235 47
Certificates of Membership	58 20
Other expenditures	157 12
Transferred to Savings Bank Deposit	40 31
Balance on hand	697 06
	$12 412 96

The funds of the Society are as follows, par values being stated:

Fellowship Fund:

79 Subscriptions to Nov. 6th, 1878		$8 000 00	
Accumulated interest to Nov. 6th, 1878		886 12	
Received during past year 1 Subscription		150 00	
" " " " Interest on bonds		560 00	
" " " " Interest from Savings Bank		40 31	
		9 636 43	
Expended from fund during year for publications		710 00	
		8 926 43	
Present condition: 80 Subscriptions	$8 150 00		
Accumulated interest	776 43		
			$8 926 43

The Fellowship Fund is invested as follows:

8 Bonds Jersey City Water Loan	$8 000 00	
Deposit in Seamen's Bank for Savings	926 43	
Norman Medal Fund:		
1 Certificate Croton Aqueduct Stock, New York City		1 000 00
General Investment:		
10 Shares New York Central and Hudson River R. R. Stock	1 000 00	
1 Consolidated Certificate New York Central and Hudson River R. R. Stock	35 00	
		1 035 00

J. J. R. CROES,
Treasurer.

REPORTS OF COMMITTEES.

Report of the Committee on Finance.

Presented and Accepted at the Twenty-Seventh Annual Meeting.

The Committee on Finance respectfully presents the following report for the year ending November 5th, 1879:

The balance of funds on hand, as reported Nov. 6th, 1878, was

Cash	$ 749 51
Invested funds	10 921 12
Total	$11 770 63

The amount of cash received from Nov. 6th, 1878, to Nov. 5th, 1879, as reported is $11 663 45

Balance on hand Nov., 1878	749 51
Total	$12 412 96
Disbursements	11 715 90
Balance on hand	697 06
Invested funds	10 961 43
Total	$11 658 49

For the full details from which the foregoing has been condensed, you are respectfully referred to the Treasurer's Report.

One year since we were congratulated upon emerging from debt, to accomplish which it was necessary to economize, and curtail expenses in every possible direction, and thus the publication of our transactions remained sadly behind.

During the past year these have been brought up to date without involving us again in debt, so that the expenses of a year and a half of publishing has been borne during the past year, and we think it proper to remind the Society of the vast amount of extra labor which has been done by the Secretary and Treasurer, who have had the principal labor of editing, publishing, and distributing so many columns in addition to the usual number in the same space of time.

We have found the accounts systematically and carefully kept, and so conveniently arranged that the labor of examination is greatly facilitated, with very little danger of errors occurring or escaping notice.

Very respectfully submitted,

W. H. Paine,
C. V. Smith,
George S. Greene, } *Committee.*

Report of Committee on the Gauging of Streams.

Presented at the Annual Meeting, Nov. 5th, 1879.

The Committee have not yet been able to secure the desired co-operation of observers in communicating to the Society the results of continuous measurements of rainfall and flow of streams. There are, without doubt, many systematic observations made of the height of water in storage reservoirs and ponds used for city water supply and manufacturing purposes. With the aid of a few measurements giving the form and length of over-falls of dams, and the dimensions of pipes, gates, conduits, and race-ways, these notes could be made available for the information desired. The Committee again call the attention of members to desirability of collecting and forwarding all possible statistics on this subject, to be collated and put in useful shape. If the observers are unable, from want of time or other reasons, to reduce the notes, the original observations, if preserved in the Society, would furnish a mass of information which could be put into useful form by any one desirous of using it.

With a view to arousing more interest in the matter, the Committee have prepared some plain, practical suggestions to observers, which are offered for discussion and which it is proposed to issue to all who are in position to secure records of the kind desired.

Apart from the question of continuous records of flow, it is very desirable to have notes of the maximum and minimum discharge of streams of known water-shed. The records of this kind are scattered through reports and professional journals which are not easily accessible. Members are requested to furnish any memoranda of this kind to the Committee for collation and publication. Notes of the least flow and of the dry-weather flow of streams are greatly needed, the term "dry-weather flow" meaning the mean discharge during several weeks when the stream is at its lowest, and usually, though not always, including the period of 24 or 48 hours of least discharge.

There is probably a certain ratio existing between the area and the least flow which may be expected, depending more on the character of the water-shed than on either the mean or least recorded rain-fall.

We are not in possessien of enough records to determine this ratio with any accuracy.

Such notes as we can obtain are presented in the following table, the publication of which may induce members of the Society and others to contribute additional memoranda on the subject:

Table of the Least Flow of Streams.

Name.	Drainage Area, Square Miles.	Date of Observation.	Discharge in Cubic feet per Second per square mile.	Authority.
West Branch Croton River, New York	20.37	Aug. 31, 1870.	0.016	J. J. R. Croes.
Hale's Brook, Mass	24.	Sept. 7, 1876.	0.135	J. P. Frizell, evidence, Boston Water suits.
Sudbury River, Mass	76.3	July 21, 1876.	0.079	A. Fteley, " " "
Charles River, Mass	236.	Sept. 6, 1845.	0.188	J. P. Kirkwood, Mass. St. Bd. Health, 7th Rep.
Croton River	339.	Sept. 6, 1833.	0.178	Gauging by D. B. Douglass.
Concord River, Mass	352.	Sept. 14, 1876.	0.296	C. Herschel, evidence, Boston Water suits.
Housatonic, Ct	790.	Oct. 15, 1878.	0.165	H. Loomis, Rept. N. Y. Com. Pub. Works, 1879.
Passaic, N. J	855.	Oct. 10, 1878.	0.208	J. J. R. Croes and G. W. Howell.
Schuylkill, Pa	1 800.	Sept , 1874.	0.210	E. F. Smith, Rept. Phila. Water Commissioners.
Merrimack	3 598.	July 25, 1840.	0.414	J. B. Francis, quoted by J. P. Kirkwood.
Connecticut	10 234.	Aug. 27, 1876.	0.521	T. G. Ellis, gauging for U. S. Govt.

Table of Flood Discharges of Streams.

Name.	Drainage area, square miles.	Date of observation.	Discharge in cubic feet per second per square mile.	Authority.
South Branch, N. Y.	7.8	1869.	73.92	N. Y. State Counsel, Black River case.
Woodhull Resr., N. Y.	9.4	1869.	77.76	" "
W. Branch, Croton River	20.37	Jan. 7, 1874.	54.43	J. J. R. Croes.
Cochituate, Mass.	19.	1869.	17.38	J. P. Davis.
Watuppa Lake, R. I.	28.5	June 10, 1875.	72.00	W. Rotch.
Flat River, R. I.	61.	1843.	120.75	J. H. Shedd.
Sudbury, Mass.	76.3	March 26, 1876.	42.17	A. Fteley.
Nashua, Mass.	84.5	....	71.14	E. Sawyer.
Nashua, "	109	1848.	104.50	"
Nashua, S. Br., Mass.	122	1870.	56.21	"
Pawtuxet, R. I.	190	1867.	56.85	J. H. Shedd.
Croton, N. Y.	339	April 20, 1854.	74.87	Calculated from Reports Croton Aq. Dept.
Black River, N. Y.	523	1869.	36.80	N. Y. State Counsel, Black River case.
Passaic, N. J.	881	Dec. 12, 1878.	20.33	J. J. R. Croes.
Merrimack, Mass.	4 136	1852.	23.40	C. Herschel.
Connecticut, Ct.	10 234	May, 1854.	20.27	C. Herschel.

While a knowledge of the probable least discharge is desirable in connection with questions of water supply and water power, the greatest probable flood discharge of streams is important to be known in connection with the designing of all structures over or in flowing waters.

Reliable notes on this subject are also very rare. Several efforts have been made to determine formulæ expressing the discharge in terms of the drainage area, but without much success.

In the accompanying table a number of observed maximum discharges of American streams are arranged according to size of drainage area. Several of these are taken from the paper by J. H. Shedd in Transactions A. S. C. E., Vol. IV, p. 301, but with the discharge given in cubic feet per second per square mile of area instead of per minute per acre. It is believed that the number of instances of extraordinary freshets can be largely increased by contributions from members having such records in their possession.

In remarkable contrast with the discharges in this table is that of the Seine in France, in the flood of March 17, 1876, which was said to be the greatest since 1807, and in which the discharge was only 3.48 cubic feet per second per square mile. The drainage area is 16 860 square miles. (Annales des Ponts et Chaussées, Vol. XIII. p. 435.)

It will be observed that all of the streams above named are in the Northern Atlantic States.

It is an interesting subject of inquiry whether the same general rule will apply to the maximum and minimum discharge of streams in this region and those in the Southern Atlantic Slope, and those in the Mississippi Valley and on the Pacific Slope. The Committee request memoranda bearing on this subject.

J. James R. Croes,
Chairman.

AWARD OF THE NORMAN MEDAL AND NORMAN BOOK PRIZE

For the Year ending August 1st, 1879.

Competition for the Norman Medal has heretofore been restricted to papers offered especially for that purpose. Under the new Code of Rules adopted by the Board of Direction, with the approval of the donor of the Medal Fund, George H. Norman, Member and Fellow of the Society, all the original papers presented to the Society by members of any class during the year ending August 1st, 1879, have been submitted to a Board of Censors, designated as directed by those rules. This Board for the past year was composed of the following members of the Society: E. S. Chesbrough, Charles Paine, C. Shaler Smith. The Board reports that the Norman Medal should be awarded to Edward P. North, Member Am. Soc. Civ. Eng., for the paper "*The Construction and Maintenance of Roads.*" The Norman Prize of Books to Max E. Schmidt, Member Am. Soc. Civ. Eng., for the paper "*The South Pass Jetties.*" The Board also reports that several of the other papers presented during the year are deserving of high praise.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

		Date of Election.
CANFIELD, EDWARD	Assistant Engineer, N. Y., L. E. & W. R. R., Mansion House, Buffalo, N. Y.	December 3, 1879.
HARRIS, HENRIQUE	Chief Engineer, N. Y. & Manhattan Beach Railroad, 402 Sackett street, Brooklyn, N. Y.	" " "
LOOMIS, HORACE	Assistant Engineer, Department of Public Works, Room 11½ City Hall, New York	November 5, 1879.
MCKEE, CHARLES H.	Assistant Engineer, Delaware & Hudson Canal Co., Albany, N. Y.	June 4, 1879.
MCKEOWN, THOMAS	Chief Engineer, Marquette & Mackinaw R. R., Detroit, Mich.	December 3, 1879.
MITCHELL, HENRY	Chief of Physical Hydrography, U. S. Coast Survey, 1 Ellis street, Roxbury Station, Boston, Mass.	January 7, 1880.
NICHOLS, AURIN B.	Engineer of Railroads, Department of the Interior, Washington, D.C.	" " "
ROCKWELL, SAMUEL	Civil Engineer, 18 East Fourteenth street, New York City, N. Y.	" " "
STROBEL, CHARLES L.	Principal Assistant, Keystone Bridge Co., Pittsburg, Pa.	December 3, 1879.

ASSOCIATE.

LAWSON, LEONIDAS M.	92 Broadway, New York	December 3, 1879.

CHANGES AND CORRECTIONS.

MEMBERS.

BILLIN, CHARLES E. ..... 4039 Locust street, Philadelphia, Pa.

BROWN, CHARLES O. ..... Tunja, United States of Colombia.

BUCK, LEFFERT L. ..... 1632 Rhode Island avenue, N. W., Washington, D. C.

BURDEN, JAMES A. ..... 139 Fifth avenue, New York City, N. Y.

DORSEY, EDWARD B.....61 Broadway, New York City, N. Y.

GREENE, GEORGE S..... .94 Chestnut street, Boston, Mass.

KATTE, WALTER.....Chief Engineer, New York Elevated Railroad, 6 Bowling Green, New York City, N. Y.

KNAPP, LOUIS H.....Deputy City Engineer, 410 Franklin street, Buffalo, N. Y.

MACLEOD, JOHN .....547 Second street, Louisville, Ky.

MCDOWELL, NATHAN M....Alleghany City, Pa.

OSGOOD, JOSESPH O.....Division Engineer, N. M. & S. P. R. R. Care of A. A. Robinson, Esq., Chief Engineer, Pueblo, Colorado.

RICHARDSON, HENRY B....Assistant Engineer, Board of State Engineers, St. Joseph, Tensas Parish, La.

STAUFFER, D. MCN.....Contractor's Office, Dorchester Bay Tunnel, Boston, Mass.

TALCOTT, COOK.....Chief Engineer, Astoria & Winnemucca Railroad, P.O. Box 446, Portland, Oregon.

WALLING, HENRY F.....Eaton, Preble Co., Ohio.

FELLOW.

GILMAN, CHARLES C.....President Hawkeye Telegraph Co., Eldora, Iowa.

DEATH.

EDGE, GEORGE W.....Elected member March 4th, 1874. Died January 1st, 1880.

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